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Contents

Original Scientific Articles

- Trisha Ghosh, Chamundeeswari Duraipandian, Govindasamy Karuppasamy,
Elayaraja Masilamani, Yuni Astuti, Bekir Erhan Orhan, Farjana Akter Bobby,
Kambitta Valappil Ibnu Noufal, Robert Çitozi and Vlad Adrian
**Geantă Analyzing the Impact of Integrated Yoga and Neuro-Linguistic Programming
on Blood Pressure, Stress, Anxiety, and Parenting Sense of Competence in Mothers
of Adolescents: A Randomized Controlled Trial 477-485**
- Feni Norrahmah, Shery Iris Zalillah, I Dewa Made Aryananda Wijaya Kusuma, Imam Syafii,
Arif Bulqini, Muhammad Kharis Fajar and Muhammad Bagus Firzam Bharlaman
**Using Small-Sided Games or Their Combination with Speed Endurance Training: Which
Is More Effective for Improving Aerobic Capacity in Young Amateur League Soccer Players? 486-491**
- Wahyu Dwi Yulianto, Endang Rini Sukamti, Fauzi, Trisnar Adi Prabowo, Ristanti Puji Astuti,
Septiana Dwi Rakhmawati, Maulana Aditya Pamungkas and Satria Yudi Gontara
**Phenomenological Study: Analyzing the Role and Meaning of Sports Performance in The Lives
of Wheelchair Student-Athletes..... 492-500**
- Titis Pambudi, FX Sugiyanto, Tomoliyus, Ilham, Bekir Erhan Orhan and Vlad Adrian Geantă
Defining the Influence of Age and Gender on Key Performance Metrics in Badminton..... 501-510
- Ahadi Priyohutomo, Komarudin and Sridadi
**The Perspective of Physical Education Teachers: Challenges within the Project-Based
Learning Model 511-517**
- Ahmad Alfian Wahyu Baskoro, Waristra Tyo Nirwansyah,
Muhamad Fauzi Antoni and I Dewa Made Aryananda Wijaya Kusuma
**Enhancing Lower Limb Strength in Amateur Soccer Players: Assessing the Impact of Repeated
Sprint Training in Tactical Soccer Drills 518-523**
- Mashud, Syamsul Arifin, Herita Warni, Aryadi Rachman, Amka, Muhammad Fadillah,
Pebriyandi, Miftah Fariz Prima Putra, Wahyu Indra Bayu and Novi Yanti
**Developing Students' Movement Independence: Internalizing Physical Literacy
in Project-based Physical Education Learning..... 524-532**
- Jordan Miranda Pocaan
**Conducting a Core-Based Exercise Program in Movement Competency Training Course
to Improve Pain Tolerance and Abdominal Endurance of Female University Students
with Primary Dysmenorrhea 533-539**

Kukuh Hardopo Putro, Suharjana, Agus Susworo Dwi Marhaendro, Awan Hariono, Siswantoyo, Fauzi, Endang Rini Sukamti and Trisnar Adi Prabowo Evaluating Validity and Test-retest Reliability on Indonesian Basketball Talent Scouting Model for Athletes Aged 10 to 14	540-547
Awaluddin, Samsudin, Wahyuningtyas Puspitorini, Widiatuti Widiastuti and Syahrudin A Comprehensive Approach to Enhancing Volleyball Skills: The Role of Problem-Based Learning, Constraint-Led Approach, and Motivation	548-555
Abdi Gudeta Taye, Houari Bouchher, Md. Hamidur Rahman, Ricardo Ricci Uvinha, Amensisa Kebede Legesse, Dritan Adili and Dessalegn Wase Mola Determining the Influence of Coaches, Parents, and Stakeholders on the Development of Youth Football: A Comprehensive Analysis.....	556-565
Fabio Scamardella, Francesco Tafuri, Giulia Amato, Francesca Latino and Maria Giovanna Tafuri Anthropometric Aspects and Athletic Performance in Women's Tennis.....	566-574
Jusuf Blegur Proactive Decision-Making of Physical Education Teachers in Enhancing Competence through Further Studies: A Comparative Study	575-582
Natalia Shchepotina, Viktor Kostiukevych, Inna Asauliuk, Svitlana Dmytrenko, Vadym Adamchuk, Volodymyr Yakovliv and Tamara Chernyshenko Programming of the Training Process for Qualified Female Volleyball Players in the Preparatory Period of the Annual Training.....	583-593
Pahala Tua Hutajulu, Johansyah Lubis and Apriyanto Tirta Understanding the Influence of Combined Teaching Styles on Football Passing Performance among PETE Freshmen Students.....	594-600
Ricko Irawan, Bambang Priyono, Soedjatmiko, Imam Ciptaning Wahyu Santoso, Agung Wahyudi and Adi S Biomechanical Kinetic Chain Analysis of Service Motion for Speed Ball Prediction Through SBM-03 App Development	601-608
Oksana Blavt, Gennadii Iedynak, Lesia Galamanzhuk, Tetiana Helzhynska, Yurii Kachurak, Julia Mykhalska, Liubov Levandowska and Rostyslav Tymkovych Software and Hardware Control System for Implementing the Balance Error Scoring System	609-617
Gopal Chandra Saha, Chandan Shaw, Bekir Erhan Orhan, Prem Kumar Karak, Smriti Mondal, Shantanu Halder, Subhashis Biswas and Bidya Roy The Impact of Targeted Soccer Training Interventions on YO-YO Intermittent Recovery Test Performance in University-Level Soccer Players	618-624
Mostafa Errama, Mustapha Bassiri, Atifi Jaafar and Said Lotfi Assessing the Efficiency of Reduced Positional Games in Soccer: A Multivariate Analysis of Technical and Tactical Indicators According to Different Playing Systems	625-632
Rosario Ceruso, Genoveffa De Cesare, Arben Kaçurri, Agron Kasa and Giampiero Merati From Pitch to Console: Exploring the Role of Football eSports in the Development of Young Footballers	633-641

Omar Ben Rakaa, Carla Lourenço, Mustapha Bassiri and Said Lotfi The Effect of Adapted Physical Activity and Inclusive Sport on the Motivation and Psychological Health of Children with Disabilities: A Randomized Control Trial	642-651
Fabio Scamardella, Francesca Latino and Maria Giovanna Tafuri Anthropometric Characteristics of Young Bocce Athletes in the Raffa Specialty: An Analysis of Physical Parameters in Junior Players of National Level.....	652-659
Sohom Saha, Simran Obhrai, Richa Vishwakarma, Prabir Mondal, Nagesh, Bharat Prasad, Kautilya Upadhyay and Dev Karan Singh Clarifying the Impact of Small-Sided Games and HIIT on Anaerobic Endurance in Adolescent Hockey Players	660-667
Vardan Geghamyan, Ira Poghosyan and Sahak Hovhannisyan The Impact of Competitive Regulatory Changes on Psychological Indicators Ensuring the Efficiency of a Wrestler's Performance	668-674
Svitlana Marchenko Study of the Factor Structure of Motor Fitness in 8-Year-Old Boys During the Process of Mastering the “Kin Geri” Kick Technique.....	675-683
Review Articles	
Carola Costanza, Francesco Paolo Colecchia, Rita Polito, Marcellino Monda, Marco Carotenuto, Giovanni Messina, Antonietta Monda, Nicola Mancini, Fiorenzo Moscatelli, Giuditta Bargiacchi and Maria Ruberto Martial Arts and ADHD: A Narrative Review of Cognitive, Behavioral, and Epigenetic Effectse..	684-690
Carla Lourenço, Omar Ben Rakaa, Mustapha Bassiri and Said Lotfi Unravelling the Impact of Universal Design for Learning on the Inclusion of Students with Disabilities in Physical Education: A Systematic Review	691-704
Gatot Jariono, Nurhidayat, Eko Sudarmanto, Haris Nugoho and Fadilah Umar The Impact of Adaptive Physical Education on the Physical and Cognitive Development of Children with Special Needs: A Literature Review	705-718
Raehang, La Ode Adhi Virama and Dewangga Yudhistira Identifying Challenges and Opportunities in the Implementation of Mobile Learning in Physical Education: A Literature Review	719-724
Andhega Wijaya, Dwi Lorry Juniarisca, Aprilyan Putra Bimantoro, Shidqi Hamdi Pratama Putera, La Ode Adhi Virama, Dewangga Yudhistira Using a Reflective Research Approach on the Implementation of Teaching Games for Understanding in Physical Education: A Scoping Review	725-733
Retraction Note	
Retraction Note: Engaging in Short-Term Moderate-Intensity Exercise Increases Growth Hormone Levels in Individuals with Obesit (Physical Education Theory and Methodology, 24(4), 619–625. https://doi.org/10.17309/tmfv.2024.4.14).....	734
Editorial Process	735

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Травень 2025. Том 25, № 3

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Зміст

Оригінальні наукові статті

- Тріша Гош, Чамундешварі Дурайпандіан, Говіндасамі Каруппасамі, Ілаяраджа Масіламані, Юні Астуті, Бекір Ерхан Орхан, Фарджана Актор Бобі, Камбіта Валаппіл Ібн Нуфал, Роберт Сітоджі, Влад Адріан Джіанте
Аналіз впливу інтегрованої практики занять йогою та нейролінгвістичного програмування на показники артеріального тиску, стресу, тривожності та відчуття батьківської компетентності у матерів дітей підліткового віку: Рандомізоване контрольоване дослідження 477-485
- Фені Норрахма, Шері Іріс Заліллах, І Діва Маде Аріананда Віджая Кусума, Імам Сьяфії, Аріф Булкіні, Мухаммад Харіс Фаджар, Мухаммад Багус Фірзам Бхарламан
Використання ігор неповними складами або їх поєднання із тренуванням швидкісної витривалості: Яка методика ефективніша для покращення аеробної продуктивності юних футболістів аматорської ліги? 486-491
- Вахю Дві Юліанто, Енданг Ріні Сукамті, Фаузі, Тріснар Аді Прабово, Рістанті Пуджі Астуті, Септіана Дві Рахмаваті, Маулана Адітья Памунгкас, Сатрія Юді Гонтара
Феноменологічне дослідження: Аналіз ролі та значення спортивної результативності в житті студентів-спортсменів на інвалідних візках 492-500
- Тітіс Памбуді, ФХ Сугіянто, Томоліус, Ільхам, Бекір Ерхан Орхан, Влад Адріан Геанта
Визначення впливу віку та гендеру на ключові показники результативності в бадмінтоні... 501-510
- Ахаді Пріяхутам, Комарудін, Шрідаді
Погляд вчителів фізичного виховання: Труднощі в рамках використання моделі методу проєктів в навчанні 511-517
- Ахмад Альфіан Вахю Баскоро, Варістра Тіо Нірвансіях, Мухаммад Фаузі Антоні, І Дева Маде Арьянанда Віджая Кусума
Підвищення силових якостей нижніх кінцівок у футболістів-аматорів: Оцінка впливу повторних спринтерських тренувань у тактичних футбольних вправах 518-523
- Машуд, Шьямсул Аріфін, Херіта Варні, Арьяді Рахман, Амка, Мухаммад Фадиллах, Пабріанді, Міфтах Фаріз Прима Путра, Вахью Індра Байю, Нові Янті
Розвиток рухової самостійності учнів: Інтерналізація фізичної грамотності в процесі навчання фізичного виховання з використанням проєктів 524-532
- Джордан Міранда Покаан
Проведення програми на основі комплексу вправ для м'язів кора в рамках тренувального курсу з розвитку рухової компетентності щодо покращення показників толерантності до болю та абдомінальної витривалості студенток ВНЗ з первинною дисменореєю 533-539

Кукух Хардопо Путро, Сухарджана, Агус Сусворо Дві Мархаендро, Аван Харіоно, Сісвантойо, Фаузі, Енданг Ріні Сукамті, Тріснар Аді Прабово Оцінювання валідності та тест-ретестової надійності індонезійської моделі пошуку талантів у баскетболі для спортсменів віком від 10 до 14 років.....	540-547
Авалуддін, Самсудін, Вахюнінгтіас Пуспіторіні, Відіатуті Відіастуті, Сяхруддін Комплексний підхід до підвищення спортивної майстерності у волейболі: Роль проблемно-орієнтованого навчання, обмежено-керуваного підходу та мотивації.....	548-555
Абді Гудета Тайе, Хуарі Бушер, Мад. Хамідур Рахман, Рікардо Річчі Увінья, Аменсіса Кебеде Легессе, Дрітан Аділі, Дессалеґн Васе Мола Визначення впливу тренерів, батьків та зацікавлених сторін на розвиток дитячо-юнацького футболу: Комплексний аналіз.....	556-565
Фабіо Скамарделла, Франческо Тафурі, Джулія Амато, Франческа Латіно, Марія Джованна Тафурі Антропометричні аспекти та спортивна результативність у жіночому тенісі	566-574
Юсуф Блегур Проактивне ухвалення рішень викладачів фізичного виховання щодо підвищення компетентності через подальше навчання: Порівняльне дослідження	575-582
Наталя Щепотіна, Віктор Костюкевич, Інна Асаулюк, Світлана Дмитренко, Вадим Адамчук, Володимир Яковлів, Тамара Чернишенко Програмування тренувального процесу кваліфікованих волейболісток у підготовчому періоді річного циклу підготовки	583-593
Арала Туа Хутаджулу, Йохансія Лубіс, Априянто Тірто Розуміння впливу комбінованих стилів викладання на результативність виконання пасів у футболі серед студентів-першокурсників програми підготовки вчителів фізичного виховання	594-600
Ріко Іраван, Бамбанг Прійоно, Соеджатміко, Імам Чіптанінг Вахью Сантосо, Агунг Вахьюді, Аді С Біомеханічний аналіз кінетичного ланцюга руху подачі щодо прогнозування швидкості польоту м'яча шляхом розроблення додатку SBM-03	601-608
Оксана Блавт, Геннадій Єдинак, Леся Галаманжук, Тетяна Гельжинська, Юрій Качурак, Юлія Михальська, Любов Левандовська, Ростислав Тимкович Програмно-технічна система контролю для реалізації системи підрахунку помилок балансу...	609-617
Гопал Чандра Саха, Чандан Шау, Бекір Ерхан Орхан, Прем Кумар Карак, Смріті Мондал, Шантану Халдер, Субхашіс Бісвас, Бідія Рой Вплив цільових тренувальних інтервенцій з футболу на результативність Йо-Йо тесту переривчастого відновлення у футболістів університетського рівня	618-624
Мостафа Еррама, Мустафа Бассірі, Джаафар Атіфі, Саїд Лотфі Оцінювання ефективності редукованих позиційних ігор у футболі: Багатовимірний аналіз техніко-тактичних показників відповідно до різних систем гри.....	625-632
Розаріо Серузо, Дженовеффа Де Чезаре, Арбен Качуррі, Агрон Каса, Гаймп'єро Мераті На шляху від футбольного поля до ігрової консолі: Вивчення ролі футбольного кіберспорту в розвитку юних футболістів.....	633-641

Омар Бен Ракаа, Карла Лоуренсо, Мустафа Бассірі, Саїд Лотфі
Вплив адаптованої фізичної активності та інклюзивного спорту на мотивацію та психологічне здоров'я дітей з інвалідністю: Рандомізоване контрольоване дослідження... 642-651

Фабіо Скамарделла, Франческа Латіно, Марія Джованна Тафурі
Антропометричні характеристики юних спортсменів з бочче за спеціалізацією «Раффа»: Аналіз фізичних параметрів юних гравців національного рівня 652-659

Сохом Саха, Сімран Обхрай, Річа Вішвакарма, Прабір Мондал, Нагеш, Бхарат Прасад, Каутілья Упадхьяй, Дев Каран Сінгх
З'ясування впливу ігор неповними складами та методу високоінтенсивного інтервального тренування на анаеробну витривалість у хокеїстів підліткового віку 660-667

Вардан Гегамян, Іра Погосян, Саак Ованесян
Вплив регуляторних змін у змагальній діяльності на психологічні показники, що забезпечують ефективність виступу борця 668-674

Світлана Марченко
Дослідження факторної структури рухової підготовленості хлопців 8 років у процесі оволодіння технікою удару ногою «kin geri» 675-683

Оглядові статті

Карола Костанца, Франческо Паоло Колеккіа, Ріта Політо, Марчелліно Монда, Марко Каротенуто, Джованні Мессіна, Антонієтта Монда, Нікола Манчіні, Фіоренцо Москателлі, Джудітта Барджаккі, Марія Руберто
Бойові мистецтва та розлад дефіциту уваги з гіперактивністю: Наративний огляд когнітивних, поведінкових та епігенетичних впливів 684-690

Карла Лоуренсо, Омар Бен Ракаа, Мустафа Бассірі, Саїд Лотфі
Виявлення впливу універсального дизайну навчання на інклюзію учнів з інвалідністю у фізичному вихованні: Систематичний огляд 691-704

Гатот Джаріоно, Нурхидаят Нурхидаят, Еко Сударманто, Харіс Нугохо, Фаділа Умар
Вплив адаптивного фізичного виховання на фізичний та когнітивний розвиток дітей з особливими потребами: Огляд літератури 705-718

Раехан, Ла Ода Адхі Вірама, Девангга Юдхістіра
Визначення викликів та можливостей у впровадженні мобільного навчання на заняттях з фізичного виховання: Огляд літератури..... 719-724

Андхега Віджая, Дві Лоррі Джуніариска, Априлян Путра Біманторо, Шидкі Хамді Пратама Путера, Ла Ода Адхі Вірама, Девангга Юдхістіра
Використання рефлексивного дослідницького підходу щодо впровадження методики навчальних ігор для тренування розуміння у фізичному вихованні: Огляд предметного поля 725-733

Повідомлення про відкликання

Повідомлення про відкликання: Заняття короткотривалими фізичними вправами помірної інтенсивності підвищують рівень гормону росту в осіб з ожирінням (Теорія та методика фізичного виховання, 24(4), 619–625. <https://doi.org/10.17309/tmfv.2024.4.14>)..... 734

Етапи редакційного процесу 735



Analyzing the Impact of Integrated Yoga and Neuro-Linguistic Programming on Blood Pressure, Stress, Anxiety, and Parenting Sense of Competence in Mothers of Adolescents: A Randomized Controlled Trial

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Abstract

Background. Mothers of adolescents face unique stressors that can adversely affect their mental health and family dynamics. Implementing effective interventions is essential to address maternal stress and anxiety in this population.

Objectives. This study aimed to evaluate the effects of yoga alone and yoga combined with Neuro-Linguistic Programming (NLP) on physiological state, stress and anxiety management in mothers of adolescent children.

Materials and methods. A randomized controlled trial was conducted in the Chennai Metropolitan Area, involving 90 mothers (aged 35-55 years) of adolescents (aged 13-19 years). Participants were randomly assigned to one of three groups: control (n = 30), yoga (n = 30), or yoga with NLP (n = 30). The yoga group engaged in 60-minute yoga sessions thrice weekly for 12 weeks, while the yoga with NLP group participated in the same yoga regimen plus weekly 90-minute NLP sessions. The control group received no intervention. Primary outcomes included blood pressure, heart rate, salivary cortisol, Perceived Stress Scale (PSS), Hamilton Anxiety Rating Scale (HAM-A), and Parenting Sense of Competence (PSOC) scale, measured at baseline and post-intervention.

Results. In the post-intervention period, significant between-group differences were observed across all outcomes ($p < 0.001$). The yoga with NLP group demonstrated the greatest improvements, with reductions in systolic (119.93 ± 3.87 mmHg) and diastolic blood pressure (82.93 ± 3.37 mmHg), heart rate (74.90 ± 8.86 bpm), cortisol (14.17 ± 1.91 mg/dL), PSS (13.80 ± 2.73), and HAM-A (16.67 ± 2.55) scores, alongside increased PSOC scores (79.33 ± 6.35). The yoga-only group exhibited moderate enhancements, while the control group showed no changes.

Conclusions. The findings suggest that combined yoga and NLP significantly reduced stress and anxiety, as well as improved physiological outcomes in mothers of adolescents, highlighting its potential as an effective intervention.

Keywords: yoga, neuro-linguistic programming, mother, stress, anxiety, cortisol.

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Introduction

Mothers of adolescents face unique stressors that can significantly impact their mental health and well-being (Ghosh et al., 2024; Sharda, 2022). Transitioning to adolescence often increases family conflict, concerns about children's safety and development, and challenges in maintaining effective communication and parenting practices (Shaw et al., 2021). These factors can contribute to elevated levels of stress and anxiety among mothers, potentially affecting both maternal health and family dynamics (Lanjekar et al., 2022). Women, in general, are at higher risk for stress-related disorders, with prevalence rates of anxiety and depression nearly twice that of men (Höglund et al., 2020). This gender disparity is particularly pronounced during reproductive years, highlighting the need for targeted interventions for women's mental health. Parenting stress, defined as the psychological distress arising from the demands of the parenting role, has been consistently associated with negative outcomes for both mothers and children (Delvecchio et al., 2020). For mothers of adolescents, this stress can be exacerbated by the increasing autonomy and risk-taking behaviours characteristic of this developmental stage (Mak et al., 2020).

Furthermore, chronic stress and anxiety in women have been linked to a range of physical health problems (Pramanik, et al., 2023; Pramanik, et al., 2023), including cardiovascular disease, immune dysfunction, and accelerated cellular ageing (Lyons et al., 2023). While various interventions have been explored to address maternal mental health, there is growing interest in holistic approaches that target both physiological (Vignesh et al., 2024) and psychological aspects of stress and anxiety. Yoga, focusing on mindfulness (Thanalakshmi et al., 2024), breathwork, and physical postures, has shown promise in reducing stress and improving emotional regulation (Hilcove et al., 2021; Ks et al., 2023). Concurrently, Neuro-Linguistic Programming (NLP), a psychotherapeutic approach emphasizing cognitive restructuring and communication skills, has demonstrated efficacy in anxiety management across diverse populations (Ybias et al., 2024). However, the potential synergistic effects of combining these modalities, particularly for mothers of adolescents, remain largely unexplored. This study aims to address this gap by investigating the combined impact of yoga and NLP on stress and anxiety management in mothers of adolescent children, compared to yoga alone and a control condition.

Materials & Methods

Study Design and Participants

This randomized controlled trial investigated the effects of yoga and combined yoga with Neuro-Linguistic Programming (NLP) on stress and anxiety management in mothers of adolescent children. The study enrolled 90 participants, aged 35-55 years, each with at least one child between 13-19 years old. Participants were randomly (See Figure: 1) assigned by lottery method to one of three groups: control, yoga, or yoga with NLP, with 30 individuals per group. The study received approval from the Ethics Committee at Meenakshi Academy of Higher Education & Research in Tamil Nadu (Approval No. MMCH&RI IEC/

PhD/02/JAN/2023)—additionally, all study procedures adhered to the most recent version of the Declaration of Helsinki.

Sample Size Calculation

The sample size was determined using G*Power software version 3.1.9.2 (Kang, 2021). The calculation was based on a one-way ANOVA with three groups, assuming a medium effect size ($f = 0.50$), an alpha level of 0.05, and a desired power of 0.80. The researchers increased the sample size by approximately 20% to account for potential dropouts and ensure sufficient power for subgroup analyses. This resulted in a total target sample of 90 participants, with 30 individuals allocated to each of the three groups (control, yoga, and yoga with NLP).

Inclusion and Exclusion Criteria

Inclusion criteria required the ability to understand and follow instructions in the local language and willingness to participate for the entire study duration. Exclusion criteria encompassed prior experience with yoga or NLP, current participation in other stress management programs, diagnosed psychiatric disorders requiring medication, and physical conditions interfering with yoga practice.

Interventions

Yoga Group: The Yoga Group participated in 60-minute sessions thrice weekly for 12 weeks. The yoga program incorporated a variety of loosening exercises, asanas, pranayama, and meditation techniques. The loosening exercises included Cat-Cow Breathing, Vaksha Sakti Vikasha, and Surya Namaskarasana from the Bihar School of Yoga tradition. This was followed by Sashangasana (Child Pose), Ustrasana, Matsyasana, Setubandhasana, Bhujangasana, and Makarasana to improve flexibility and spinal mobility. The pranayama practices focused on Shitali, Bhramari, and Nadi Suddhi, while the mental chanting of A-U-M was also included. The NLP component incorporated the Anchoring, De-Busting, and Swish techniques to enhance cognitive restructuring, stress management, and practical communication skills.

Yoga with NLP Group: Besides the yoga program described above, this group received weekly 90-minute Neuro-Linguistic Programming (NLP) sessions for 12 weeks. The NLP program focused on cognitive restructuring, stress management techniques, and communication skills to enhance parenting competence (See Table 1).

Control Group: Participants in this group received no intervention but were offered the opportunity to participate in yoga and NLP sessions after completing the study.

Procedure

Before the 12-week intervention, participants in both active groups attended two 90-minute familiarisation sessions to introduce fundamental concepts, demonstrate techniques, and address questions. All participants received structured log books to record daily stress levels, significant parenting-related events, and practice techniques outside

Table 1. Intervention details for Yoga and NLP program

Training Component	Duration	Frequency
Loosening Exercises		
Cat-Cow Breathing	5 minutes	3 times/week
Vaksha Sakti Vikasha	5 minutes	3 times/week
Surya Namaskarasana	10 minutes	3 times/week
Asanas		
Sashangasana (Child	5 minutes	3 times/week
Ustrasana	5 minutes	3 times/week
Matsyasana	5 minutes	3 times/week
Setubandhasana	5 minutes	3 times/week
Bhujangasana	5 minutes	3 times/week
Makarasana	5 minutes	3 times/week
Pranayama]	5 minutes	3 times/week
Shitali Pranayama]	5 minutes	3 times/week
Bhramari Pranayama	5 minutes	3 times/week
Nadi Suddhi	5 minutes	
Meditation		
A-U-M Chanting	10 minutes	3 times/week
NLP Techniques		
Anchoring	30 minutes	1 times/week
De-Busting	30 minutes	1 times/week
Swish	30 minutes	1 times/week

scheduled sessions. The yoga and yoga with NLP groups also logged their session attendance. These log books, collected and reviewed biweekly by the research team, served to monitor compliance, gather qualitative data, and encourage participant engagement and self-reflection throughout the study period.

Outcome Measures

Blood Pressure: Systolic and diastolic blood pressure was measured using a standard sphygmomanometer following American Heart Association guidelines. Measurements

were taken in a seated position after 5 minutes of rest (Borah et al., 2023).

Heart Rate: Heart rate was measured using a standard pulse oximeter, with readings taken after 5 minutes of rest in a seated position.

Cortisol: Salivary cortisol levels were measured using liquid chromatographic methods and mass spectrometry (LC-MSMS). Samples were collected in the morning (8-9 AM) to control for diurnal variations. LC-MSMS is 10–100 times more sensitive than RIA or IA and has a higher degree of specificity (Inder et al., 2012).

Perceived Stress Scale (PSS): This 10-item self-report questionnaire assesses the degree to which situations in one's life are appraised as stressful. Scores range from 0 to 40, with higher scores indicating higher perceived stress (Reis et al., 2010).

Hamilton Anxiety Rating Scale (HAM-A): This 14-item clinician-administered scale measures the severity of anxiety symptoms. Scores range from 0 to 56, with higher scores indicating more severe anxiety (Hamilton, 1959).

Parenting Sense of Competence (PSOC) scale: This 17-item self-report measure assessed parents' satisfaction with parenting and their self-efficacy in the parenting role. Higher scores indicate greater competence and satisfaction with parenting (Gilmore & Cuskelly, 2024).

Statistical Analysis

Demographic data were collected at baseline, and all outcome measures were assessed pre-and post-intervention by trained research assistants blinded to group allocation. Data analysis was performed using SPSS version 25.0 (Morgan et al., 2004). Descriptive statistics were calculated for all variables, with between-group differences analyzed using one-way ANOVA for continuous variables and chi-square tests for categorical variables. Paired t-tests assessed within-group changes from baseline to post-intervention. Statistical significance was set at $p < 0.05$.

Results

140 potential participants were initially screened for eligibility in this study. After applying the inclusion and exclusion criteria, 90 individuals met the requirements

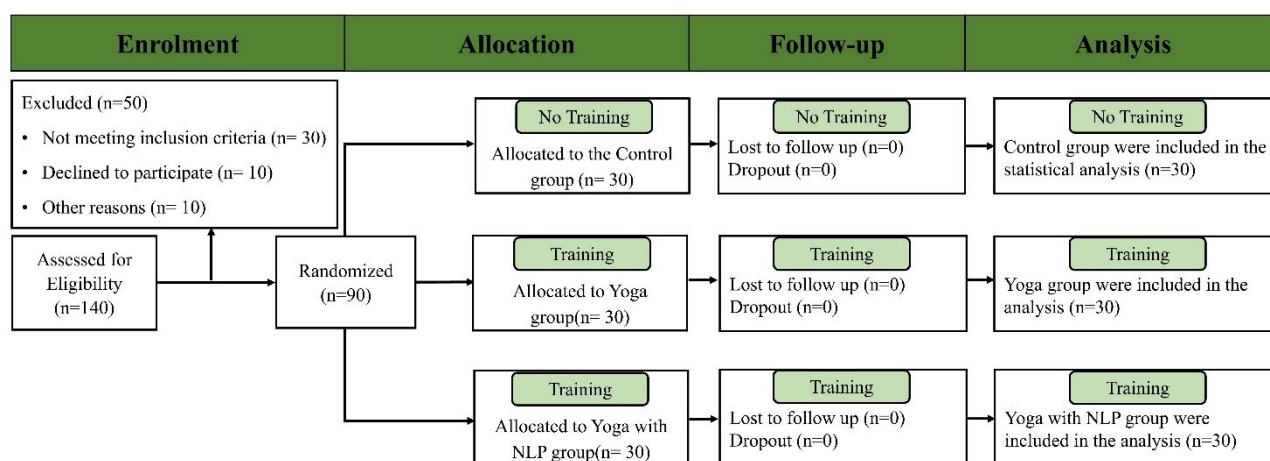


Fig. 1. Semantic representation

Table 2. Demographical details of the study participants

Characteristic	Overall, n = 90	Control, n = 30	Yoga, n = 30	Yoga with NLP, n = 30	p-value
Age (yrs)	44.38 (5.14)	44.03 (2.86)	43.90 (3.01)	45.20 (7.92)	>0.9
Height (cm)	153.41 (4.03)	154.03 (4.05)	153.00 (3.84)	153.20 (4.26)	0.5
Weight(kg)	68.58 (8.73)	69.54 (10.13)	67.46 (7.90)	68.73 (8.15)	0.8
Qualification					0.9
Degree and Above	54 (60%)	18 (60%)	18 (60%)	18 (60%)	
Graduate	33 (37%)	12 (40%)	11 (37%)	10 (33%)	
HSC	3 (3.3%)	0 (0%)	1 (3.3%)	2 (6.7%)	
Occupation					>0.9
Housewife	9 (10%)	2 (6.7%)	4 (13%)	3 (10%)	
Private sector	52 (58%)	19 (63%)	16 (53%)	17 (57%)	
Public sector	10 (11%)	3 (10%)	3 (10%)	4 (13%)	
Self Employed	19 (21%)	6 (20%)	7 (23%)	6 (20%)	
Annual Income					0.5
> 7 laks	18 (20%)	3 (10%)	7 (23%)	8 (27%)	
1-3 laks	15 (17%)	6 (20%)	6 (20%)	3 (10%)	
3-7 laks	47 (52%)	19 (63%)	13 (43%)	15 (50%)	
No income	10 (11%)	2 (6.7%)	4 (13%)	4 (13%)	
Marital Status					0.7
Divorced	7 (7.8%)	2 (6.7%)	2 (6.7%)	3 (10%)	
Married	80 (89%)	28 (93%)	27 (90%)	25 (83%)	
Widow	3 (3.3%)	0 (0%)	1 (3.3%)	2 (6.7%)	
Family status					0.8
Joint	13 (14%)	5 (17%)	3 (10%)	5 (17%)	
Nuclear	77 (86%)	25 (83%)	27 (90%)	25 (83%)	
No Children					0.15
One child	66 (73%)	25 (83%)	23 (77%)	18 (60%)	
Three child	2 (2.2%)	1 (3.3%)	0 (0%)	1 (3.3%)	
Two child	22 (24%)	4 (13%)	7 (23%)	11 (37%)	
No boys					0.3
No boy	28 (31%)	11 (37%)	11 (37%)	6 (20%)	
One boy	57 (63%)	19 (63%)	17 (57%)	21 (70%)	
Two boy	5 (5.6%)	0 (0%)	2 (6.7%)	3 (10%)	
No girls					0.8
No girls	48 (53%)	16 (53%)	17 (57%)	15 (50%)	
One girl	37 (41%)	11 (37%)	12 (40%)	14 (47%)	
Two girls	5 (5.6%)	3 (10%)	1 (3.3%)	1 (3.3%)	
Children Home					0.8
Home	67 (74%)	21 (70%)	23 (77%)	23 (77%)	

and were enrolled in the trial (see Figure 1). specifically, one participant dropped out from the control group, two participants discontinued from the yoga group, and three participants withdrew from the yoga with NLP group. Despite these dropouts, the overall retention rate remained high, with 93.3% of participants completing the entire study protocol. The final analysis included 29 participants in the

control group, 28 in the yoga group, and 27 in the yoga with NLP group, for 84 participants who completed the entire study. The mean age of participants was 44.38 ± 5.14 years, with no significant differences (See Table 2) between groups in demographic characteristics such as age, height, weight, qualification, occupation, annual income, marital status, family status, or number of children (all $p > 0.05$). Most

Table 3. Comparison of baseline outcome parameters between the groups

Characteristic	Overall, n = 90	Control, n = 30	Yoga, n = 30	Yoga with NLP, n = 30	p-value
SBP (mmHg)	136.64 (8.76)	134.50 (6.66)	138.07 (6.91)	137.37 (11.65)	0.2
DBP_(mmHg)	97.91 (5.70)	97.70 (6.37)	97.50 (5.11)	98.53 (5.68)	0.8
Heart rate (bpm)	97.43 (8.75)	94.17 (6.77)	96.07 (9.07)	102.07 (8.48)	0.001
Cortisol (mg/dl)	16.99 (1.11)	17.16 (1.02)	16.98 (0.90)	16.82 (1.37)	0.6
PSS	34.72 (4.16)	35.27 (4.33)	34.77 (3.85)	34.13 (4.35)	0.5
HAM-A	27.92 (3.25)	27.30 (3.72)	27.77 (2.96)	28.70 (2.96)	0.3
PSOC	42.43 (4.87)	43.17 (5.75)	42.93 (4.19)	41.20 (4.44)	0.3

SBP: systolic blood pressure; DBP: diastolic blood pressure; PSS: perceived stress scale; HAM-A: Hamilton Anxiety Rating Scale; PSOC: Parenting Sense of Competence

Table 4. Post-intervention comparison of the outcome parameters between the groups

Characteristic	Overall, n = 90	Control, n = 30	Yoga, n = 30	Yoga with NLP, n = 30	p-value
SBP (mmHg)	128.59 (8.58)	137.20 (6.00)	128.63 (4.54)	119.93 (3.87)	<0.001
DBP_(mmHg)	89.24 (8.34)	97.87 (7.61)	86.93 (4.55)	82.93 (3.37)	<0.001
Heart rate (bpm)	81.82 (13.08)	92.83 (6.08)	77.73 (14.74)	74.90 (8.86)	<0.001
Cortisol (mg/dl)	14.97 (1.93)	16.43 (1.38)	14.31 (1.58)	14.17 (1.91)	<0.001
PSS	24.13 (9.25)	34.83 (3.82)	23.77 (3.37)	13.80 (2.73)	<0.001
HAM-A	22.22 (5.78)	28.30 (3.69)	21.70 (3.46)	16.67 (2.55)	<0.001
PSOC	61.51 (16.23)	42.87 (6.08)	62.33 (6.46)	79.33 (6.35)	<0.001

SBP: systolic blood pressure; DBP: diastolic blood pressure; PSS: perceived stress scale; HAM-A: Hamilton Anxiety Rating Scale; PSOC: Parenting Sense of Competence

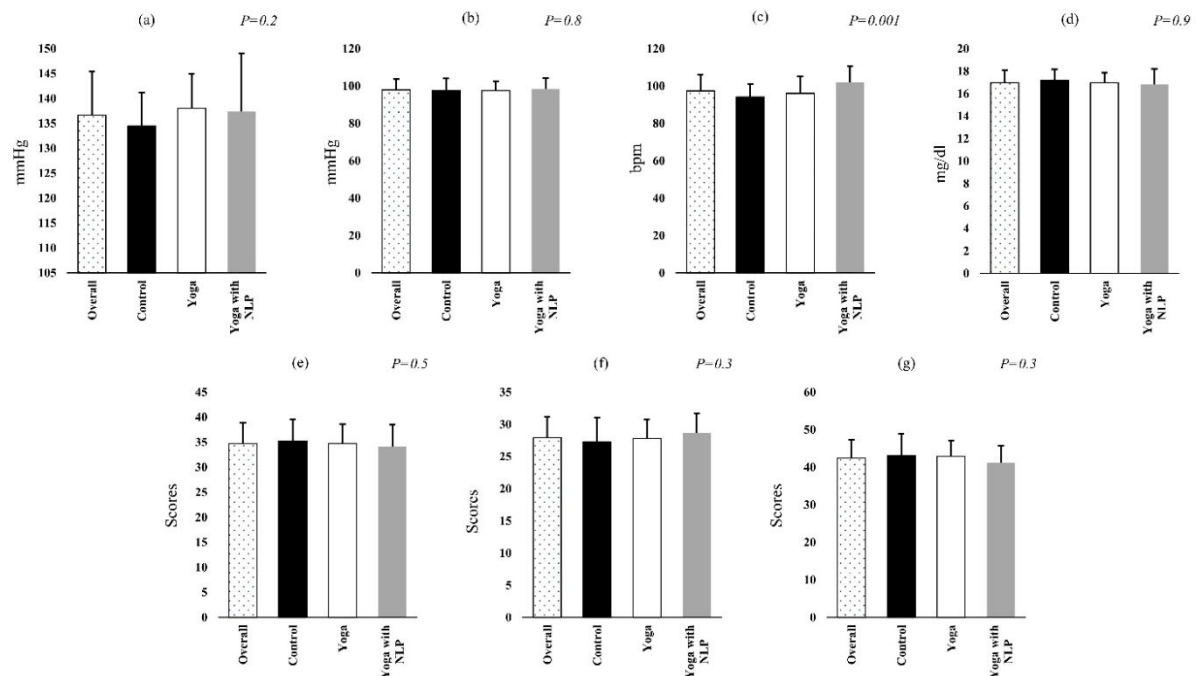


Fig. 2. Baseline comparison on (a) SBP, (b) DBP, (c) Heart rate, (d) Cortisol, (e) PSS, (f) HAM-A, (g) PSOC outcome parameters

participants (60 %) had a degree or higher education, worked in the private sector (58%), earned 3-7 lakhs annually (52%), were married (89%), and lived in nuclear families (86%).

The majority had one child (73 %), with 63 % having one boy and 41 % having one girl.

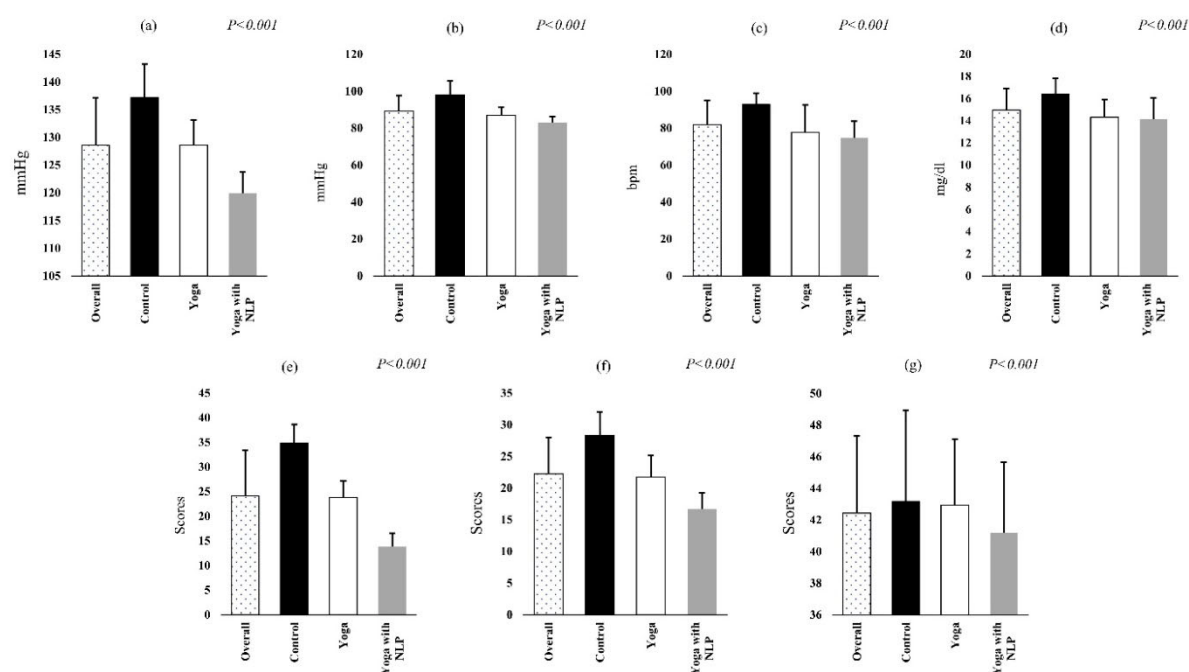


Fig. 3. Post-intervention comparison on (a) SBP, (b) DBP, (c) Heart rate, (d) Cortisol, (e) PSS, (f) HAM-A, (g) PSOC outcome parameters

At baseline, there were no significant (see Table: 3) differences between groups in systolic blood pressure (SBP), diastolic blood pressure (DBP), cortisol levels, Perceived Stress Scale (PSS) scores, Hamilton Anxiety Rating Scale (HAM-A) scores, or Parenting Sense of Competence (PSOC) scores (all $p > 0.05$). However, a significant difference in heart rate was observed ($p = 0.001$), with the yoga with NLP group showing a higher baseline rate (102.07 ± 8.48 bpm) compared to the control (94.17 ± 6.77 bpm) and yoga-only (96.07 ± 9.07 bpm) groups. Figure 2 displays a graphical representation of the baseline comparison.

Post-intervention measurements (see Table 4) revealed significant differences between groups for all outcomes (all $p < 0.001$). The yoga with NLP group demonstrated the most substantial improvements, followed by the yoga-only group, while the control group showed little to no change. Specifically, the yoga with NLP group exhibited the lowest blood pressure (SBP: 119.93 ± 3.87 mmHg; DBP: 82.93 ± 3.37 mmHg), heart rate (74.90 ± 8.86 bpm), and cortisol levels (14.17 ± 1.91 mg/dl). This group also reported the lowest stress (PSS: 13.80 ± 2.73) and anxiety (HAM-A: 16.67 ± 2.55) scores, along with the highest parenting sense of competence (PSOC: 79.33 ± 6.35). The yoga-only group showed intermediate improvements, while the control group maintained elevated levels similar to baseline measurements. Figure 3 displays a graphical representation of the post intervention comparison.

Discussion

The present study demonstrated significant improvements in physiological and psychological measures of stress and anxiety among mothers of adolescent children following yoga and combined yoga with NLP interventions. The yoga with NLP group showed the most substantial benefits across all outcome measures, including reduced blood pres-

sure, heart rate, cortisol levels, perceived stress, anxiety, and increased parenting sense of competence. The yoga-only group also exhibited improvements, albeit to a lesser extent, while the control group maintained baseline levels.

A quasi-experimental study examined the effects of hatha yoga on stress, anxiety, and depression in 52 Iranian women (mean age 33.5 ± 6.5 years). Participants completed a 4-week intervention of thrice-weekly 60-70-minute yoga sessions. Using the DASS-21 scale, significant reductions in depression, anxiety, and stress were observed post-intervention ($p < 0.001$). The study concludes that yoga can effectively reduce these psychological symptoms and maybe a complementary treatment approach (Khunti et al., 2023). Another pilot study examined the effectiveness of an 8-week mindful parenting intervention (MPI) for 21 parents of children aged 3-7 years with anxiety disorders, and the findings showed that there were significant increases in mindful parenting and reductions in dysfunctional parent-child interactions ($p < 0.05$) (Farley et al., 2023). The present study extends these findings by demonstrating the enhanced benefits of combining yoga with NLP techniques.

A systematic review found evidence that NLP interventions can effectively reduce anxiety across various populations and settings (Nompo et al., 2021). Several studies demonstrated that NLP techniques like reframing, anchoring, rapport building, and modelling helped decrease anxiety symptoms and promote positive behavioural changes (Kotera et al., 2019). The NLP approaches were applied through average multi-session training programs lasting 2-12 weeks. Common elements included identifying sensory preferences, establishing rapport, reframing negative thoughts, and practising new cognitive and communication strategies. The benefits extended beyond merely reducing anxiety, encompassing enhancements in self-confidence, communication skills, and overall mental health (Nompo et al., 2021; Shirazi & Kahrzei, 2022).

The synergistic effect of yoga and NLP may be attributed to their complementary mechanisms. Yoga's focus on breath control, mindfulness, and physical postures likely contributes to reduced physiological arousal and improved emotional regulation (Padmavathi et al., 2023). NLP techniques, on the other hand, may enhance cognitive restructuring and communication skills, thereby addressing the psychological aspects of stress and anxiety more directly (Mehdi et al., 2022). The combined approach offers a more comprehensive strategy for managing the multifaceted challenges mothers of adolescents face.

This study's strengths include its randomized controlled design, physiological and psychological outcome measures, and the comparison of yoga alone versus yoga with NLP. However, limitations should be noted. The sample size was relatively small, and the study was conducted in a single geographic location, potentially limiting generalizability. Additionally, the long-term sustainability of the observed benefits was not assessed, as follow-up measurements beyond the immediate post-intervention period were not conducted.

Conclusions

In conclusion, this study provides evidence for the efficacy of combined yoga and NLP interventions in reducing stress and anxiety among mothers of adolescent children. The findings suggest that this integrated approach may be more effective than yoga alone in improving physiological and psychological well-being. Future research should explore the long-term effects of these interventions, investigate potential mechanisms of action through neuroimaging or biomarker studies, and examine the impact on family dynamics and adolescent outcomes. Given the promising results, healthcare providers and community organizations may consider combining yoga and NLP programs as a holistic approach to supporting maternal mental health and family well-being.

Conflict of Interest

The authors declare that they have no conflicts interests.

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Аналіз впливу інтегрованої практики занять йогою та нейролінгвістичного програмування на показники артеріального тиску, стресу, тривожності та відчуття батьківської компетентності у матерів дітей підліткового віку: Рандомізоване контрольоване дослідження

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

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Історія питання. Матері підлітків стикаються з особливими стресовими факторами, які можуть негативно впливати на їхнє психічне здоров'я та сімейну динаміку. Впровадження ефективних інтервенцій має важливе значення для подолання материнського стресу та тривожності у цій категорії населення.

Мета дослідження. Мета цього дослідження полягала в оцінюванні впливу занять йогою як самостійної практики та поєднання йоги з нейролінгвістичним програмуванням (НЛП) на процес регулювання фізіологічного стану, рівнів стресу і тривожності у матерів дітей підліткового віку.

Матеріали та методи. Рандомізоване контрольоване дослідження проведено у метрополійній території Ченнай із залученням 90 матерів (віком 35-55 років), які виховують підлітків (віком 13-19 років). Учасників було розподілено за методом рандомізації до однієї з трьох груп: контрольної ($n = 30$), групи, що займалася йогою ($n = 30$), або групи, що поєднувала йогу з НЛП ($n = 30$). Група з йоги займалася 60-хвилинними заняттями тричі на тиждень впродовж 12 тижнів, тоді як група, що практикувала йогу з НЛП, дотримувалася аналогічного режиму йоги та щотижневих 90-хвилинних сеансів НЛП. У контрольній групі не проводилося жодних інтервенцій. Первинні результати включали вимірювання артеріального тиску, частоти серцевих скорочень, рівня кортизолу в слині, показників шкали сприйнятого стресу (Perceived Stress Scale, PSS), шкали Гамільтона для оцінки рівня тривожності (Hamilton Anxiety Rating Scale, HAM-A) і шкали відчуття батьківської компетентності (Parenting Sense of Competence, PSOC) на початковому етапі та після завершення інтервенції.

Результати. У постінтервенційному періоді спостерігалися достовірні міжгрупові відмінності за всіма показниками ($p < 0,001$). Група, яка займалася йогою з НЛП, продемонструвала максимальне поліпшення показників: зниження систолічного ($119,93 \pm 3,87$ мм рт.ст.) і діастолічного артеріального тиску ($82,93 \pm 3,37$ мм рт.ст.), частоти серцевих скорочень ($74,90 \pm 8,86$ уд./хв.), рівня кортизолу ($14,17 \pm 1,91$ мг/дл), шкали PSS ($13,80 \pm 2,73$) і шкали HAM-A ($16,67 \pm 2,55$), а також підвищення результатів за шкалою PSOC ($79,33 \pm 6,35$). У групі, яка практикувала лише заняття йогою, спостерігалось помірне покращення, тоді як у контрольній групі змін не зафіксовано.

Висновки. Отримані дані свідчать про те, що комбінована практика, яка поєднує в собі заняття йогою та НЛП, сприяє значному зменшенню рівня стресу та тривожності, а також покращує фізіологічні показники у матерів підлітків, що підкреслює потенціал цієї методики як ефективної інтервенції.

Ключові слова: йога, нейролінгвістичне програмування, мати, стрес, тривожність, кортизол.

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Using Small-Sided Games or Their Combination with Speed Endurance Training: Which Is More Effective for Improving Aerobic Capacity in Young Amateur League Soccer Players?

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Abstract

Objectives. This study aimed to analyze the differences in the effects of Small-Sided Games (SSG) and a combination of Small-Sided Games with Speed Endurance Training (SSG+SET) on the aerobic capacity of young amateur league soccer players, as measured by total distance coverage and $\text{VO}_{2\text{max}}$.

Materials and methods. A total of 36 young amateur league soccer players were selected as samples and divided into two groups using the matching-group technique. The average sample characteristics were 20.08 ± 0.97 years of age, 170.47 ± 4.77 cm in height, 62.98 ± 5.89 kg in weight, and a body mass index of 20.08 ± 0.97 kg/m². Both groups underwent 12 training sessions over four weeks, with a frequency of three sessions per week. Aerobic capacity was measured using the Yo-Yo Intermittent Recovery Test Level 1 to evaluate total distance coverage and $\text{VO}_{2\text{max}}$ before and after the intervention.

Results. Both training methods had a positive impact on improving aerobic capacity. However, the group undergoing the SSG+SET combination showed significantly greater improvements compared to the SSG-only group ($p < 0.05$). The SSG+SET group demonstrated a larger increase in total distance coverage and higher $\text{VO}_{2\text{max}}$ values, reflecting physiological adaptations such as improved oxygen utilization efficiency and cardiovascular function.

Conclusions. The findings indicate that the combination of Small-Sided Games and Speed Endurance Training is more effective in enhancing the aerobic capacity of young amateur league soccer players, particularly in terms of total distance coverage and $\text{VO}_{2\text{max}}$. This method offers a comprehensive approach to improving physical fitness while simultaneously supporting the development of technical and tactical skills through specific game simulations.

Keywords: small-sided games, speed endurance training, total distance coverage, $\text{VO}_{2\text{max}}$, young amateur soccer players.

Introduction

Soccer is a complex sport involving various essential physical components such as aerobic endurance, anaerobic endurance, strength, power, speed, and agility (Akyildiz et al., 2022; Komarudin et al., 2022). Among these, aerobic endurance forms the foundation, as it is critical to sustaining performance during a match that lasts 90 minutes or more (Harrison et al., 2015). Players are required to maintain

physical intensity throughout the match, including running, fast walking, and sustaining optimal performance levels (Bangsbo et al., 2006; Ouertatani et al., 2022; Scott et al., 2014). Overall physical fitness significantly impacts game performance, as players with better physical conditions are more capable of maintaining consistent performance and handling pressure from opponents in dynamic game situations (Gonçalves et al., 2016; Mujika et al., 2018).

In modern soccer, achieving an optimal combination of technical and physical abilities is crucial. Therefore, a systematic and well-planned training program, including periodization, is necessary to attain high levels of strength and endurance (Turner & Stewart, 2014; Williams et al., 2017). An ideal training program must be holistic to better

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reflect the realities of gameplay (Esposito et al., 2024; Larsen et al., 2014). The success of training depends significantly on this holistic approach, as partial or unrealistic training models may hinder players' development (Ribeiro et al., 2022).

A holistic approach to soccer training integrates physical, technical, and tactical aspects relevant to game demands (Kusuma, Kusnanik, Lumintuarso, & Phanpheng, 2024). This approach enables players to enhance physical fitness while improving skills and game understanding. In addition to creating training conditions that simulate real-match scenarios, it helps maximize players' potential, reduce injury risk, and improve adaptation to the ever-changing dynamics of the game. Thus, the holistic approach is a fundamental necessity for improving players' overall performance.

Small-sided games (SSG) have become a highly popular training model among soccer coaches. This training method has proven effective in improving player performance, both in terms of physical fitness and technical abilities. However, with the increasing intensity demands of modern soccer, SSG alone is often insufficient to prepare players optimally for high-intensity matches. Therefore, combining SSG with other training methods, such as Speed Endurance Training (SET), is needed to comprehensively meet players' physical needs.

A popular holistic training method in soccer is the combination of Speed Endurance Training (SET) and Small-Sided Games (SSG) (Kusuma, Kusnanik, Lumintuarso, Setijono, et al., 2024). This combination provides a comprehensive solution for creating training scenarios that closely resemble real-match conditions. SET improves players' physical performance, while SSG, involving small-field games with short durations, not only contributes to aerobic fitness improvement but also incorporates technical-tactical aspects and players' actual movements (Clemente & Sarmiento, 2021; Iaia & Bangsbo, 2010). Previous studies have shown that the combination of SSG and high-intensity running-based training offers significant benefits for players' aerobic capacity (Rabbani et al., 2019).

This approach is expected to address the issue of separating physical and technical training while preparing players comprehensively to face various game challenges. This study aims to demonstrate the effectiveness of combining SSG and SET in improving soccer players' performance and compare the impact of the SSG+SET combination with SSG-only training. Thus, this research seeks to provide in-depth insights into the significant benefits of this approach in enhancing players' physical and technical qualities.

This study hypothesizes that the combination of Speed Endurance Training (SET) and Small-Sided Games (SSG) has a significant effect on improving soccer players' aerobic capacity. Additionally, this holistic approach is expected to simultaneously enhance players' technical-tactical abilities, offering advantages in more realistic and competitive gameplay contexts.

Materials and methods

Study participants

This study involved 36 randomly selected participants, consisting of young soccer players competing in amateur

leagues. The average sample characteristics included an age of 20.08 ± 0.97 years, a height of 170.47 ± 4.77 cm, a weight of 62.98 ± 5.89 kg, and a body mass index of 20.08 ± 0.97 kg/m². This population was chosen to represent young players at the amateur level, ensuring the study findings provide relevant insights to support the development of their physical performance.

Study Organization

The research employed an experimental method with a randomized parallel matched-group design, dividing the sample into two distinct groups. The 36 participants were split evenly, with 18 players assigned to the SSG Group and 18 players to the SSG+SET Group. Group allocation was conducted using a matched-group approach, beginning with an initial test using the Yo-Yo Intermittent Recovery Level 1 Test (YYIR1) for all participants. Test results were used to rank participants by score, from highest to lowest. Participants were paired sequentially, such as the top scorer with the second-highest scorer, and so on until all participants were paired. Each pair was then randomly assigned to one of the intervention groups.

Statistical Analysis

Mean (average) and standard deviation (SD) were used to describe the data. Normality and differences in means were analyzed using the Shapiro-Wilk test, while aerobic capacity (total distance, VO2 max level) differences between the SSG and SSG+SET groups were examined using the Mann-Whitney U test. A p-value of < 0.05 was considered statistically significant.

Training Program

SSG+SET Training Program combines Small-Sided Games (SSG) and Sprint Endurance Training (SET) to improve players' physical fitness and skills. The field was divided into three areas: Area 1 (SSG 1) and Area 3 (SSG 2) were used for SSG sessions, each measuring 20×40 meters, while Area 2 served as a 20-meter sprint zone connecting Area 1 and Area 3. Three groups of six players each were formed: one group trained, while the other two engaged in active recovery by passing the ball on the sidelines. The training began with Group 1 performing a combination of SSG and sprints as follows: playing SSG for 18 seconds in Area 1, sprinting 20 meters to Area 2, playing SSG for 18 seconds in Area 3, and sprinting back to Area 2. This pattern was repeated 4 times per repetition, covering a total of 80 meters in sprints and 72 seconds of SSG play. In one session, Group 1 completed 8 repetitions, sprinting a total of 640 meters and playing SSG for 576 seconds. The work-to-rest ratio was 1:2, with 88 seconds of activity followed by 176 seconds of rest per repetition. The net training duration per session was 35 minutes and 12 seconds (264 seconds per repetition × 8 repetitions). After one repetition, the groups rotated to ensure all players had the opportunity to train and enough time for active recovery (Bharlaman et al., 2024).

The Small-Sided Games (SSG) training used a 6v6 + 6 neutral player format in a 20×20 meter area with a 2:1 ratio of work to rest (2 minutes work, 1-minute rest) over 10 repetitions. The session started with Team A vs. Team

B, while Team C acted as neutral players. After 1 minute, Team A rotated out to become neutral players, while Team B remained on the field to compete against Team C. This rotation continued, with each team alternating roles as active players and neutral players throughout the 10 repetitions. Each repetition included a 2-minute work phase followed by a 1-minute rest phase. Total activity time per repetition was 3 minutes, resulting in 30 minutes of training time for all 10 repetitions, including work and rest periods. This format provided players with role variations, maintained game intensity, and improved tactical skills and physical fitness.

Results

Based on Table 1 above, there was an increase in total distance and VO_{2max} in both the SSG and SSG+SET groups. The SSG group demonstrated moderate improvements in both variables, while the SSG+SET group recorded greater increases. For the total distance variable, the SSG+SET group achieved higher post-test results compared to the SSG group. Similarly, for VO_{2max} , the SSG+SET group showed a more significant improvement after the intervention compared to the SSG group.

Table 1. Descriptive Data for Total Distance and VO_{2max}

Variable	SSG	SSG+SET
Pretest Total Distance (m)	1377.78 $\pm$ 387.14	1371.11 $\pm$ 323.45
Posttest Total Distance (m)	1611.11 $\pm$ 405.79	1748.89 $\pm$ 368.35
Pretest VO_{2max} (ml/kg/min)	47.98 $\pm$ 3.26	47.92 $\pm$ 2.71
Posttest VO_{2max} (ml/kg/min)	49.94 $\pm$ 3.43	51.09 $\pm$ 3.11

Values are expressed as Mean $\pm$ SD

Table 2 presents the results of the normality test for the variables analyzed. Based on the normality test results, the pretest and post-test data in all groups, both for total distance and VO_{2max} , indicate that the data distribution does not meet the assumption of normality. This is evidenced

Table 2. Normality test result

Variable	Statistic	df	Sig.
Pretest-Posttest Distance Group SSG	.8676	18	.0163
Pretest-Posttest Distance Group SSG+SET	.8780	18	.0242
Pretest-Posttest VO_{2max} Group SSG	.8756	18	.0220
Pretest-Posttest VO_{2max} Group SSG+SET	.8949	18	.0468

by significance values smaller than the tolerance threshold of 0.05. Consequently, the non-parametric Mann-Whitney test was employed to ensure the validity of the research findings and evaluate the differences between the groups.

Figure 1 presents the results of the Mann-Whitney test, indicating a significant difference between the SSG and SSG+SET groups for both total distance and VO_{2max} variables, as evidenced by a significance value of <0.05 .

Discussion

This study aimed to analyze the impact of combining Speed Endurance Training (SET) and Small-Sided Games (SSG) on the aerobic capacity of young amateur league soccer players. The pretest results indicated variability in players' aerobic fitness levels before the intervention. After undergoing 12 combined training sessions over one month, the post-test results revealed consistent improvements in the players' aerobic capacity. The combination of speed endurance training and small-sided games conducted over four weeks with a frequency of three sessions per week significantly enhanced the players' physical fitness (Clemente et al., 2021).

Both SSG and the combined SSG+SET training positively impacted the improvement of total distance covered during the running test and the players' VO_{2max} . However, statistical tests showed that the group undergoing the SSG+SET combination training demonstrated more significant improvements compared to the group that only performed SSG. This indicates that the addition of speed endurance training to small-sided game sessions provides more optimal aerobic stimulation, leading to greater enhancements in the

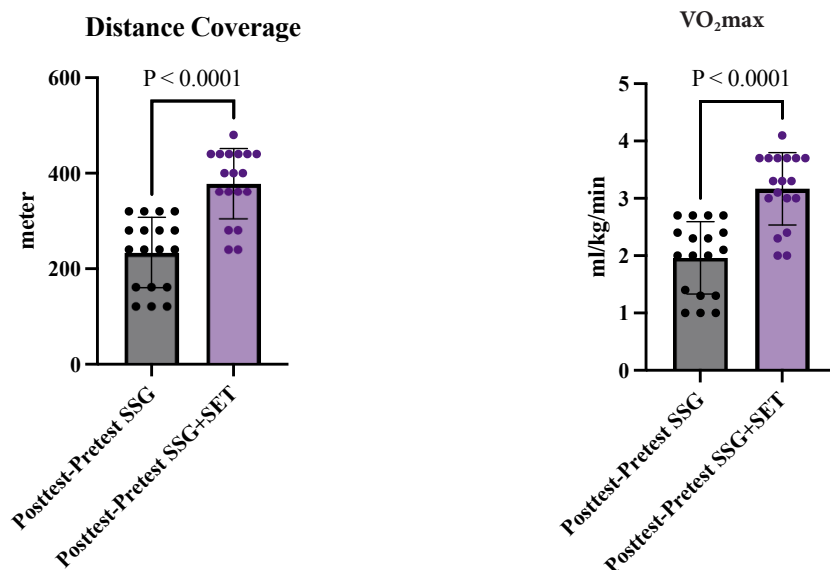


Fig. 1. Comparison of Pretest and Posttest Results for Total Distance and VO_{2max} Variables

players' aerobic capacity. This combination is considered effective in improving the physical performance of young amateur soccer players.

The average improvements suggest that the combined training enhances the players' physiological adaptations (Bharlaman et al., 2024). Adaptations such as increased maximal oxygen capacity ($\text{VO}_{2\text{max}}$), improved oxygen utilization efficiency, and enhanced lung capacity and cardiovascular function occur when players engage in high-intensity training (Atakan et al., 2021; Dunham & Harms, 2012). Additionally, the Speed Endurance Training program by Nyberg et al. (2016) reported similar findings, highlighting $\text{VO}_{2\text{max}}$ improvements as a primary indicator of aerobic capacity. High-intensity repeated training improves the body's capacity for respiratory management, reduces fatigue, and accelerates recovery. Continuous aerobic training also boosts lung capacity and cardiovascular efficiency, enabling players to sustain optimal performance for longer periods (Modric et al., 2020).

The approach used in this study emphasizes the sustainability of physical adaptations, where repeated high-intensity training progressively improves endurance, creating long-term effects that support enhanced athletic performance. Moreover, Small-Sided Games (SSG) not only contribute to the development of technical and tactical skills but also significantly impact physical fitness (Karahan, 2020). These games require players to move quickly to find space within a limited area (Guard et al., 2022; Low et al., 2020). Previous research has shown that SSG increases players' work intensity, accelerates reactions, and challenges them to manage space and time more efficiently (Rago et al., 2018). The emphasis on rapid transitions between attack and defense in SSG helps players develop mental resilience and quick thinking under pressure, which is critical in soccer matches. Research by Arslanoglu et al. (2024) also demonstrated that combined training involving aerobic speed, small-sided games, and maximal aerobic speed effectively enhances aerobic capacity and overall performance in soccer players.

This study shows that the combination of Speed Endurance Training and Small-Sided Games significantly improves the aerobic capacity of young amateur soccer players, as evidenced by Yo-Yo Intermittent Test level 1 results, which demonstrated average improvements in aerobic capacity after 12 training sessions over one month. The intervention produced physiological adaptations, including increased $\text{VO}_{2\text{max}}$, improved oxygen utilization efficiency, enhanced lung capacity, and better cardiovascular function. Additionally, this approach strengthened players' technical and tactical skills, with SSG serving as a medium to refine tactical abilities in dynamic game-like conditions. These findings align with previous studies highlighting the effectiveness of speed endurance training and small-sided games in improving aerobic fitness and physical performance. Beyond physical benefits, Small-Sided Games also enhance technical and tactical skills through simulated real-game conditions, making it a holistic and efficient training method for optimizing soccer players' performance.

Conclusions

The combination of Speed Endurance Training and Small-Sided Games has proven to be effective in enhancing the aerobic capacity of young amateur league soccer players

through significant physiological adaptations and dynamic simulations of real-game conditions.

Conflict of Interest

No potential conflict of interest was reported by the author(s).

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Використання ігор неповними складами або їх поєднання із тренуванням швидкісної витривалості: Яка методика ефективніша для покращення аеробної продуктивності юних футболістів аматорської ліги?

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 6 с., 2 табл., 1 рис., 30 джерел.

Мета дослідження. Мета цього дослідження полягала в аналізі відмінностей щодо впливу використання ігор неповними складами (ІНС) та їх комбінації із тренуванням швидкісної витривалості (ІНС+ТШВ) на рівень аеробної продуктивності юних футболістів аматорської ліги, визначений за показниками загального подолання дистанції та максимального споживання кисню (VO_{2max}).

Матеріали та методи. Загалом було відібрано 36 юних футболістів аматорської ліги, розподілених на дві групи із застосуванням методики групового зіставлення. Середній вік учасників вибірки становив $20,08 \pm 0,97$ років, зріст — $170,47 \pm 4,77$ см, вага — $62,98 \pm 5,89$ кг, індекс маси тіла — $20,08 \pm 0,97$ кг/м². Обидві групи провели 12 тренувань протягом чотирьох тижнів, з частотою три заняття на тиждень. Аеробну продуктивність вимірювали за допомогою тесту переривчастого відновлення Йо-Йо рівня 1 (the Yo-Yo Intermittent Recovery Test Level 1) з метою оцінки загального подолання дистанції та показника VO_{2max} перед початком та після завершення інтервенції.

Результати. Обидві методики тренувань позитивно вплинули на поліпшення рівня аеробної продуктивності. Однак група, яка проходила комбінацію ІНС+ТШВ, показала суттєвіші покращення порівняно з групою, в якій застосовувалась методика лише ІНС ($p < 0,05$). Група ІНС+ТШВ продемонструвала збільшення загального подолання дистанції та вищі значення VO_{2max} , що відображає фізіологічні адаптації, як-от поліпшення ефективності споживання кисню та функціонування серцево-судинної системи.

Висновки. Отримані дані свідчать про те, що поєднання ігор неповними складами та тренування швидкісної витривалості є ефективнішим методом щодо покращення рівня аеробної продуктивності юних футболістів аматорської ліги, зокрема, з точки зору загального подолання дистанції та показника VO_{2max} . Зазначений метод пропонує комплексний підхід до поліпшення рівня фізичної підготовленості, сприяючи при цьому розвитку технічних і тактичних навичок за допомогою специфічних ігрових симуляцій.

Ключові слова: ігри неповними складами, тренування швидкісної витривалості, загальне подолання дистанції, VO_{2max} , юні футболісти-аматори.

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Phenomenological Study: Analyzing the Role and Meaning of Sports Performance in The Lives of Wheelchair Student-Athletes

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Abstract

Objectives. This study aimed to analyze and understand the role and significance of sports performance in the lives of wheelchair student-athletes. It examines how sports help them navigate physical and psychological challenges, contribute to identity formation, and aid in their search for meaning in life.

Materials and methods. The study employed a descriptive quantitative approach using a survey analysis method. Additionally, unstructured interviews were conducted to strengthen the research findings and support the discussion. The sample consisted of 48 wheelchair student-athletes, categorized as follows: 12 tennis players, 12 archers, 12 athletes, and 12 fencers. The sample characteristics included an average age of 17.7 ± 8.1 years, training experience of 4.3 ± 4.2 years, and an athletic career duration of 2.1 ± 2.2 years. Among them, 13 athletes have competed at the national level, and 35 at the regional level. The research instrument was a questionnaire comprising 15 statements rated on a 1–4 scale, which has been tested for validity, resulting in four key indicators: (1) Improved Quality of Life, (2) Social Integration, (3) Search for Existence, and (4) Barriers to Participation. Data analysis used descriptive statistics and the Kruskal-Wallis test ($p < 0.05$) to examine group differences.

Results. For the Improved Quality of Life indicator, the lowest average score was observed in athletics (13.83), while the highest — in tennis (14.17). Regarding Social Integration, the lowest average score was in athletics (13.50), and the highest — in archery (13.83). For the Search for Existence indicator, the lowest average scores were observed in athletics and fencing (13.58), while the highest score was noted in archery (13.83). Regarding Barriers to Participation, the lowest average score was recorded in fencing (6.75), and the highest — in tennis (7.50). The Kruskal-Wallis value was 0.425 or $p > 0.05$, indicating no significant differences between the four wheelchair sports groups.

Conclusions. The findings indicate that wheelchair sports substantially enhance student-athletes' quality of life across various disciplines. Tennis and fencing recorded the highest perceived quality of life and the lowest barriers to participation. This study underscores the necessity for standardized facilities, enhanced support systems, and greater governmental involvement to improve student-athletes' experiences. These insights contribute significantly to both wheelchair sports literature and policy development.

Keywords: phenomenology of sports, disability sports, wheelchair student-athletes, quality of life.

Introduction

Sport has long been recognized as a vital means of enhancing quality of life, not only for physically fit individuals but

also for those with disabilities, including wheelchair athletes (Zheng et al., 2023). Research that focuses on sports achievement for people with disabilities, especially athletes who have the status of wheelchair students, is important to understand the various psychosocial and existential dimensions involved in their lives (Mindrescu, 2022). Through sport, many wheelchair athletes strive for achievement while seeking meaning and identity in life, often facing numerous physical and social limitations (Calheiros et al., 2020 & Solera et al., 2021). How-

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ever, the limited scientific studies examining the role of sports performance in helping wheelchair athletes find meaning in life highlight the need for further in-depth exploration.

Previous research on athletes with disabilities has shown that performance sports provide a platform for para-athletes to develop and affirm their identity, not only as individuals with disabilities but also as competitive athletes (Nemček et al., 2020 & Puce et al., 2023). This involvement significantly enhances their quality of life and well-being by fostering a sense of accomplishment, social inclusion, and self-improvement. Additionally, the social support athletes receive from coaches, teammates, and the broader community plays a crucial role in strengthening mental resilience and overall well-being, ultimately contributing to a better quality of life (Drózd, 2020 & Mira et al., 2023). A study on male wheelchair handball athletes identified key factors that contribute to their sense of existence, such as marital status, access to resources, full independence, regular training, and the use of customized wheelchairs (Calheiros et al., 2021). Similarly, a study conducted on 192 wheelchair basketball, wheelchair rugby, and rowing athletes in Poland concluded that high quality of life and satisfaction with health are critical in supporting the existence of para-athletes (Nowak et al., 2022). Another study involving 30 athletes across wheelchair basketball, wheelchair tennis, and wheelchair athletics further supports the notion that sports participation not only enhances physical health but also strengthens psychosocial aspects, such as emotional well-being and interpersonal relationships, both of which are crucial in affirming their existence in life (Cruz et al., 2024).

For wheelchair student-athletes, sport is more than just physical activity, but it also serves as a platform for identity formation, self-expression, and personal growth (Sarol, 2024). In Indonesia, wheelchair sports have gained greater recognition and wider support over the past decade. However, there are still significant gaps in our understanding of the complexities of these athletes' lived experiences. Wheelchair athletes frequently encounter social stigma and exclusion, in the residential environment, to the school environment making sports a crucial avenue for fostering self-worth and social inclusion (Qasim et al., 2019 & Olive et al., 2021). Failure to establish a meaningful existence in life can have serious consequences for disabled athletes. Psychologically, it can lead to low self-esteem, anxiety, and depression, resulting in social isolation and reduced opportunities in education and career (Qasim et al., 2019 & Maciá-Andreu et al., 2023). These challenges can also diminish motivation, negatively impact physical performance, loss of motivation to study and ultimately affect overall health. Therefore, it is essential for communities and organizations to provide strong psychosocial support and ensure effective social integration to promote the holistic well-being of athletes with disabilities, addressing their mental, physical, and social needs (Mandan et al., 2024).

Given these challenges, a phenomenological study is a suitable approach for examining the experiences of wheelchair student-athletes in performance sports. This research method prioritizes a deep understanding of subjective experiences and the personal meaning student-athletes assign to them (Aitchison et al., 2020; Cursiol & Barreira, 2021). Therefore, this study aims to analyze and explore the role and significance of performance sports in the lives of wheelchair student-athletes. It seeks to understand

how sports help them navigate physical and psychological challenges, how sports contribute to identity formation, and how they provide a sense of meaning in life. By adopting a phenomenological approach, this research will offer deeper insights into the subjective experiences, motivations, challenges, and successes of wheelchair student-athletes.

Materials and Methods

Study Participants

The sample for this study consisted of 48 wheelchair student-athletes from four different sports disciplines, including 12 tennis athletes, 12 archery athletes, 12 athletics athletes, and 12 fencing athletes. The sample characteristics included an average age of 17.7 ± 8.1 years, training experience of 4.3 ± 4.2 years, and an athletic career duration of 2.1 ± 2.2 years. Among them, 13 athletes have competed at the national level and 35 at the regional level. Data collection in this study was conducted following the Declaration of Helsinki and received approval from both the coaches and competition organizers.

Study Organizations

This study employed a descriptive quantitative research design with a survey analysis method to examine differences in results among wheelchair student-athletes across various sports disciplines. The research consisted of five stages. The first stage involved a comprehensive observation of different types of wheelchair sports in Indonesia to identify and formulate key research problems. Once the research problem was established, the second stage focused on document collection, gathering relevant scientific studies on student-athletes with disabilities, wheelchair athletes, the quality of life of para-athletes, and sports achievements in disability sports. This stage served as a preliminary literature review and helped in developing the research instruments. The third stage involved the development of research instruments, where the questionnaire and other tools were refined based on insights from the literature review. Additionally, a focus group discussion (FGD) was conducted with lecturers specializing in sports psychology and disability sports to assess the feasibility and validity of the research instrument.

In the fourth stage, data collection was carried out between June 2024 and January 2025 at various competitive events in wheelchair sports. The data collection process took place two to three days before each competition, following official approval from the athletes' coaches. Once the coaches granted permission, wheelchair student-athletes were invited to participate voluntarily, ensuring the principle of autonomy was upheld. To enrich the findings, unstructured interviews with wheelchair student-athletes were also conducted during this phase. The final stage involved report preparation and publication, where the research findings were compiled into a scientific paper for dissemination. This study had been formally approved by the relevant institution under approval number B/1480/UN34.16/PT.01.04/2024.

Statistical Analysis

The data analysis in this study was conducted in three stages. The first stage involved testing the instrument's validity

using the Aiken V formula (Aiken, 1985), as illustrated in Figure 1. The second stage consisted of descriptive analysis, which examined the results of the questionnaire responses collected from athletes. The third stage applied the Kruskal-Wallis test ($p < 0.05$) to analyze differences in responses among the four wheelchair sports disciplines. All data analyses were conducted using SPSS 26 (George & Mallery, 2019). The questionnaire utilized a four-point Likert scale, where 1 = “strongly disagree,” 2 = “disagree,” 3 = “agree,” and 4 = “strongly agree.”

$$V \text{ Aiken's: } \frac{\sum S}{n(c-1)}$$

S : $r - l_o$

Lo : lowest rating score

C : highest rating score

r : the score given by the assessor

Fig 1. Aiken V Formula

Results

Instrument Validity Test

The first stage of data analysis involved testing the validity of the questionnaire using Aiken V. The development of this questionnaire was part of the third stage of the

research process. The validity test was conducted by three lecturers specializing in sports psychology and two lecturers specializing in disability sports. The results of the validity test are presented in Table 1.

Based on the results in Table 1, this questionnaire consists of 15 statement items divided into four key indicators: (1) Improvement of Quality of Life, (2) Social Integration, (3) Search for Existence, and (4) Barriers to Participation. Each of these indicators is further broken down into specific sub-indicators. The first indicator, Improvement in Quality of Life, includes sub-indicators such as Physical Health and Mental Health. The second indicator, Social Integration, consists of Social Interaction and Social Support. The third indicator, Search for Existence, is represented by Self-Recognition and Role in Society. Lastly, the fourth indicator, Barriers to Participation, comprises Infrastructure, Financial Support, and Social and Cultural Factors. The Aiken V values for each statement item were all greater than 0.7, indicating that the items are valid and suitable for data collection (Susiono et al., 2024 & Wedi et al., 2024).

Descriptive Analysis

Once the questionnaire was confirmed as valid and appropriate for data collection, data was gathered from 48 wheelchair student-athletes. Following this, a second

Table 1. Questionnaire Validity Test Results

Indicator	Sub - Indicator	Statement	Item	Aiken V	Description
Improvement in Quality of Life	Physical Health	Wheelchair sports increase my physical strength	1	0.733	Valid
		Participating in sports helps maintain my cardiovascular health	2	0.800	Valid
	Mental Health	I feel happier when I am active in wheelchair sports	3	0.800	Valid
		Wheelchair sports helps reduce my stress	4	0.867	Valid
Social Integration	Social Interaction	I met many friends through wheelchair sports	5	0.867	Valid
		I feel accepted in my sporting community	6	0.867	Valid
	Social Support	I get enough moral support from fellow wheelchair athletes	7	0.733	Valid
		The coaches and support staff provided good encouragement for my development as an athlete	8	0.733	Valid
Search for Existence	Self-Recognition	I feel wheelchair sports give me more purpose in life	9	0.800	Valid
		Achievements in sports increase my self-confidence	10	0.867	Valid
	Role in Society	I feel that through wheelchair sports, I inspire others	11	0.800	Valid
		My success in sports makes me feel like an important part of society	12	0.733	Valid
Barriers to Participation	Infrastructure	I often encounter infrastructure that does not support wheelchair sports	13	0.733	Valid
	Financial Support	I feel there is a lack of financial support for wheelchair athletes like me	14	0.800	Valid
	Social and Cultural	I still feel discrimination in the sports environment	15	0.867	Valid

analysis was conducted using descriptive statistics, as presented in Table 2. The questionnaire contained 15 statement items, each rated on a 4-point scale. The Quality of Life Improvement Indicator, Social Integration Indicator, and Search for Existence Indicator each contained four statement items, resulting in a minimum possible score of 4 and a maximum score of 16. Meanwhile, the Barriers to Participation Indicator included three statement items, leading to a minimum score of 3 and a maximum score of 12.

Table 2. Descriptive Analysis Results

Indicator	Min	Max	Mean	SD
Improvement in Quality of Life				
Tennis	12	16	14.17	1.403
Archery	12	16	13.92	0.996
Athletics	12	15	13.83	0.937
Fencing	12	16	14.00	1.279
Social Integration				
Tennis	12	16	13.75	1.215
Archery	12	16	13.83	1.193
Athletics	12	15	13.50	0.905
Fencing	12	16	13.75	1.215
Search for Existence				
Tennis	12	16	14.58	1.165
Archery	12	16	13.83	1.337
Athletics	12	16	13.58	1.165
Fencing	12	15	13.58	1.311
Barriers to Participation				
Tennis	6	9	7.50	0.905
Archery	7	9	7.33	0.651
Athletics	6	8	7.08	0.793
Fencing	6	8	6.75	0.622

Based on the results in Table 2, for the Improvement in Quality of Life Indicator, the lowest average score was in Athletics (13.83), while the highest was in Tennis court (14.17). For the Social Integration Indicator, the lowest average score was in Athletics (13.50), and the highest was in Archery (13.83). In the Search for Existence Indicator, the lowest average scores were in Athletics and Fencing (13.58), while the highest was in Archery (13.83). Lastly, for the Barriers to Achievement Indicator, the lowest average score was in Fencing (6.75), and the highest was in Lawn Tennis (7.50).

Kruskal-Wallis Test

The third analysis was a Kruskal-Wallis test of group differences in the four types of wheelchair sports. The results of this test are shown in Table 3 below.

Based on Table 3, the Asymp. Sig. is 0.425 or $p > 0.05$, so there is no difference in the answers between the four wheelchair sports groups. Thus, there is no need for a post hoc test because there is no difference.

Table 3. Kruskal-Wallis Results

Questionnaire Results	
Kruskal-Wallis H	2.790
df	3
Asymp. Sig.	0.425

Discussion

After conducting data analysis and obtaining research findings, the results indicate that despite variations in sports types, technical aspects, and team dynamics, the overall impact of wheelchair sports at student level on the search for existence and the achievement of a meaningful life appears to be consistent across different sports. Therefore, the discussion in this study analyzes the descriptive results for each type of wheelchair sport. The first analysis focuses on the contribution of sports to improving the quality of life for wheelchair student-athletes. The findings show that wheelchair tennis student-athletes provided the highest ratings, while athletics student-athletes had the lowest. This difference can be explained by several scientific factors, such as varying levels of physical intensity across sports. Wheelchair tennis is a sport that often requires more intensive physical activity, which not only enhances strength and cardiovascular health but is also effective in reducing stress and increasing happiness (Grenier et al., 2023). As a result, wheelchair tennis student-athletes experience greater social interaction compared to sports like archery, which tends to be more individualistic (Ramalingam et al., 2021). Archery is considered an individualistic sport because performance is measured based on each athlete's personal skills and abilities (Wibowo et al., 2024). This individualistic nature can also lead to social isolation due to the lack of team interaction or collaboration, requiring student-athletes to develop strong mental resilience to cope with competitive pressure without direct support from teammates, coaches, or even family (Mandan et al., 2024 & Imtihansyah et al., 2024).

Moreover, differences in training opportunities and access to resources across sports may influence the assessments. Several studies indicate that access to resources such as adequate training facilities, well-structured training programs, and healthcare services also play a crucial role in enhancing the quality of life for disabled student-athletes (Luna et al., 2021, Park et al., 2022, & Wang et al., 2024). Based on the researchers' analysis, wheelchair tennis may have better facilities, more structured training, and broader support, making these athletes feel more acknowledged as professional athletes. Meanwhile, athletes in other wheelchair sports, such as archery, athletics, and fencing, primarily expressed that they were only given proper attention and treated appropriately as athletes and individuals without special needs. Additionally, other studies indirectly support the idea that providing proper care and attention to disabled student-athletes can offer greater mental stimulation and emotional support (Rakhmawati et al., 2020 & Sudarko et al., 2023). Differences in the popularity and recognition of each sport may also contribute to these variations. More popular sports, such as tennis, often receive greater community support and social validation compared to other sports (Kawakami et al., 2024), which in turn can positively

influence student-athletes' perceptions of the benefits of sports on their overall quality of life.

A second analysis focusing on Social Integration Indicators revealed that student-athletes reported the highest levels of social integration, whereas track and field athletic student-athletes gave the lowest ratings. Responses from wheelchair archery student-athletes explained that there was always intense interaction between athletes with disabilities. The results of previous studies also explain that, even though archery is individual, activities that involve togetherness between friends, such as joint training and competition in a team, can facilitate the formation of strong social bonds (Leung et al., 2020 & De Oliveira et al., 2021). In addition, this aspect is also strengthened by training arrangements that encourage moral support and encouragement from coaches and other student-athletes (Latief et al., 2024), which in turn increases feelings of acceptance and respect in the sports community.

In contrast, low scores in wheelchair athletics student-athletes may reflect a similar lack of social interaction. Track and field wheelchair athletics also explain that they only focus on pursuing time and distance targets for success. Then, the competitive nature of individual athletics allows training to be more focused on individual performance, which can reduce opportunities for in-depth social interaction (Purnomo et al., 2024). A perceived lack of moral support and encouragement that may be deemed inadequate by support staff or coaches may impact disabled athletes' and especially wheelchair athletes' perceptions of their social integration (Coates & Howe, 2023 & Mira et al., 2023). The findings on this Social Integration Indicator demonstrate the importance of community structures, environment in schools that supports their potential and support in wheelchair sports for athletic development and student-athletes' social well-being.

The third analysis of this study, which focuses on the Search for Existence Indicator, shows that archery student-athletes provided the highest ratings. However, wheelchair student-athletes generally believe that being an athlete brings positive changes in their lives. Sports play a crucial role in giving them a sense of purpose, boosting self-confidence, inspiring others, and making them feel like an essential part of society (Mandan et al., 2024 & Cruz et al., 2024). On the other hand, wheelchair student-athletes in athletics and fencing reported the lowest ratings in this aspect, indicating potential differences in how sports contribute to their search for existence and social recognition. They expressed concerns about the lack of recognition and appreciation from others, such as receiving congratulations after a competition victory or being acknowledged as athletes.

Nevertheless, they also expressed satisfaction and happiness in their roles as student-athletes. They felt recognized by fellow athletes, coaches, sports organization officials, and even the government, which provided them with material support such as monthly stipends and rewards. This support enhances their self-esteem and confidence by validating their efforts and achievements (Zheng et al., 2023) while also reducing financial burdens, allowing them to focus more on training and competition (Rodríguez Macías et al., 2023). Furthermore, such support reflects a commitment to inclusion and equality, improving public perception and fostering a more supportive and inclusive

sports environment (Calheiros et al., 2021). This support not only enhances the individual quality of life for athletes but also strengthens positive values within society as a whole.

The high scores given by archery student-athletes can be explained by several factors. Archery often requires intense concentration, precision, and dedication (Mahlovany et al., 2023). These demands may help student-athletes develop a strong sense of purpose and increased self-confidence through their achievements in the sport (Latief et al., 2024). Additionally, as a sport that receives less media attention compared to others, success in archery can create a unique and significant sense of inspiration within their community. Such achievements contribute to a greater feeling of social inclusion and enhance social interactions, reinforcing the athlete's identity as a contributing member of society (Berardi et al., 2021 & Zabala-Dominguez et al., 2023).

The fourth analysis in this study, which evaluates the Barriers to Participation Indicator, shows that wheelchair tennis student-athletes experience the highest participation barriers, whereas wheelchair fencing athletes report the lowest. Previous studies highlight that key factors influencing the participation of individuals with disabilities in sports include infrastructure that meets their specific needs (Luna et al., 2021 & Wang et al., 2024), and an inclusive environment that welcomes individuals with special needs (Aitchison et al., 2020 & Grenier et al., 2023). Further explanations from wheelchair tennis student-athletes indicate that their sport requires more complex and expensive infrastructure, including large courts often equipped with specialized accessibility features that may not be available or adequate in all locations.

On the other hand, wheelchair fencing student-athletes report fewer participation barriers, which may be due to the sport's simpler infrastructure requirements and its easier adaptability for accessibility. The smaller and possibly more close-knit wheelchair fencing community may also provide more intensive and personalized social and financial support (Villiere et al., 2021). Such conditions indirectly contribute positively to the experience of wheelchair student-athletes, as they may be less exposed to social discrimination compared to those in larger or more competitive sports environments (Kunene, 2023). To reduce participation barriers for wheelchair student-athletes, it is crucial to improve fundamental aspects of accessibility. This includes enhancing the quality of services to create a safe and comfortable training environment, such as providing easily accessible training facilities, separate training areas for wheelchair users and general participants, dedicated wheelchair-accessible pathways, health and safety guarantees, and post-retirement athlete welfare (Mandan et al., 2024, Arrum et al., 2024, & Prabowo et al., 2024). Additionally, greater involvement from the government and academic institutions is essential to encourage individuals with disabilities to participate in sports (Kasiyanto, 2023 & Nagata et al., 2023). Thus, it can help reduce social discrimination against individuals with disabilities through increased public awareness and inclusion in sports.

The main limitation of this study is that disability sports competitions, particularly wheelchair sports at the student level, remain very limited in Indonesia, making data collection challenging due to cost and time constraints. Additionally, the lack of research on wheelchair sports and student-

athlete with disabilities has led researchers to rely on broader references, such as general disability sports and Paralympic sports. The publication of this study aims to provide deeper insights into disability sports, specifically wheelchair sports. Future research should include a wider range of wheelchair sports, a larger sample size, and more detailed research methods to produce more comprehensive scientific articles with in-depth discussions.

Conclusion

This study comprehensively examines the impact of wheelchair sports on student-athletes quality of life by analyzing aspects of social integration, the search for existence, and barriers to participation across various wheelchair sports disciplines. The findings indicate that while athletes from different wheelchair sports, such as tennis, archery, athletics, and fencing, face unique challenges and benefits, wheelchair sports generally have a significant and positive impact on enhancing their quality of life. This includes improving social integration, strengthening the search for existence, and overcoming participation barriers. Wheelchair sports serve not only as a physical activity but also as a vital tool for social and emotional empowerment. Among the sports studied, wheelchair tennis was perceived to provide the highest quality of life, while fencing had the lowest barriers to participation. However, the study also highlights disparities in accessibility and support across different wheelchair sports, emphasizing the need for a more standardized approach to facility provision and athlete support. Furthermore, government and institutional involvement in improving infrastructure and support for wheelchair student-athletes is crucial in enhancing their overall experiences and outcomes. Therefore, this study makes an important contribution to the literature on wheelchair sports, guiding future policies and practices toward a more inclusive and supportive development for all wheelchair student-athletes.

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Conflict of Interest

The author has no conflict of interest regarding the author or results of other studies.

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Феноменологічне дослідження: Аналіз ролі та значення спортивної результативності в житті студентів-спортсменів на інвалідних візках

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 9 с., 3 табл., 47 джерел.

Мета дослідження. Це дослідження мало на меті проаналізувати та зрозуміти роль і значення спортивної результативності в житті студентів-спортсменів на інвалідних візках. У дослідженні розглядається питання щодо того, як спорт допомагає їм долати фізичні та психологічні труднощі, сприяє формуванню ідентичності та полегшує пошук сенсу життя.

Матеріали та методи. У дослідженні застосовано описовий кількісний підхід із використанням методу аналізу опитувань. Крім того, проведені неструктуровані інтерв'ю для підкріплення результатів дослідження та підтримки дискусії. Вибірка складалася із 48 студентів-спортсменів на інвалідних візках, які були розподілені за такими категоріями: 12 тенісистів, 12 лучників, 12 легкоатлетів і 12 фехтувальників. Характеристики вибірки включали середній вік — $17,7 \pm 8,1$ років, досвід тренувань — $4,3 \pm 4,2$ роки та тривалість спортивної кар'єри — $2,1 \pm 2,2$ роки. Серед учасників дослідження 13 спортсменів змагалися на національному рівні, 35 — на регіональному. В якості інструменту дослідження використовувався опитувальник, що складався із 15 тверджень, які оцінювалися за шкалою від 1 до 4 балів, перевірений на валідність, в результаті чого було отримано чотири ключові показники: (1) Покращення якості життя, (2) Соціальна інтеграція, (3) Пошук засобів до існування та (4) Перешкоди для участі в змаганнях. Для аналізу даних використовувалися методи описової статистики та критерій Краскела-Уолліса ($p < 0,05$) з метою вивчення групових відмінностей.

Результати. За показником «Покращення якості життя» найнижчий середній бал спостерігався в легкій атлетиці (13,83), а найвищий — у тенісі (14,17). За показником «Соціальна інтеграція» найнижчий середній бал зафіксовано в легкій атлетиці (13,50), а найвищий — у стрільбі з лука (13,83). За показником «Пошук засобів до існування» найнижчі середні бали спостерігалися в легкій атлетиці та фехтуванні (13,58), тоді як найвищий результат відзначено у стрільбі з лука (13,83). Щодо показника «Перешкоди для участі в змаганнях», найнижчий середній бал зафіксовано у фехтуванні (6,75), а найвищий — у тенісі (7,50). Значення критерію Краскела-Уолліса становило 0,425 або $p > 0,05$, що свідчить про відсутність значущих відмінностей між чотирма групами спортивних змагань на інвалідних візках.

Висновки. Результати дослідження показують, що спортивні змагання на візках суттєво підвищують якість життя студентів-спортсменів у різних дисциплінах. У тенісі та фехтуванні зафіксовано найвищий рівень сприйняття якості життя та найменші перешкоди для участі в змаганнях. Це дослідження підкреслює необхідність стандартизації умов, вдосконалення систем підтримки та більшого залучення держави з метою покращення досвіду студентів-спортсменів. Отримані дані є значним внеском як у розвиток літератури з питань вивчення спортивних змагань на візках, так і в розроблення відповідних стратегій в цій галузі.

Ключові слова: феноменологія спорту, параспорт, студенти-спортсмени на інвалідних візках, якість життя.

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Defining the Influence of Age and Gender on Key Performance Metrics in Badminton

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Abstract

Background. Badminton, a racquet sport that has gained global popularity, demands technical precision, tactical awareness, and exceptional physical fitness. Skills such as smashing, footwork, and minimizing errors are critical to success. However, the specific influence of age and gender on these metrics, especially among younger players, remains underexplored.

Objectives. This study aimed to examine the effect of age and gender on key badminton performance metrics, including smash ability, footwork, and unforced errors, in order to identify developmental and demographic factors influencing skill acquisition and execution.

Materials and methods. A quantitative descriptive study involved 24 athletes (aged 9–14) from the Wincorp badminton organization in Surakarta, Indonesia. Participants were grouped by age (9–10, 11–12, 13–14 years) and gender, ensuring equal representation. Over two months, data on smashing, lobbing, driving, footwork, and error rates were collected. Descriptive statistics and MANOVA analyzed differences, with a significance level set at $p < 0.05$.

Results. MANOVA revealed significant age-related effects on smashing ($p = 0.000$), footwork ($p = 0.000$), and error points ($p = 0.000$), with beginners (13–14 years) excelling in most metrics. Gender differences were also found to be substantial for smashing ($p = 0.000$), footwork ($p = 0.000$), and error points ($p = 0.003$), with males outperforming females in most categories. Interaction effects between age and gender were significant for smashing and footwork ($p < 0.05$). However, no considerable differences were observed for netting and serving strokes across age or gender.

Conclusions. The study indicates that age and gender significantly influence badminton performance metrics. Beginner athletes (13–14 years) demonstrated superior skills compared to younger groups, while males generally outperformed females. These findings highlight the importance of tailoring training programs by age and gender to optimize skill development and reduce performance gaps. Further studies should be performed to investigate biomechanical and psychological factors to refine coaching strategies.

Keywords: badminton, athlete characteristics, age, gender, performance metrics, smash skills, footwork.

Introduction

Badminton is widely regarded as one of the fastest racquet sports globally (Ali Siong, 2023; Pan et al., 2024; Pratama, et al., 2024; Rusdiana et al., 2023; Zubir et al., 2022), offering opportunities for players of all ages to compete across varying skill levels, including in Indonesia, where it

is trendy (Sepdanius, Rifki & Gemaini, 2023; Loureiro & Freitas, 2012). This sport is characterized by its demand for quick planning and execution of movements, rapid reaction speed, and precise temporal and spatial control, especially in positioning the racket to intercept the shuttlecock, making these competencies essential for successful players (Huang, 2023; Prajongjai et al., 2023; Lam et al., 2018). Players must also exhibit exceptional athleticism and adapt to the sport's high physical and cognitive demands (Setijono et al., 2024; Stovba et al., 2020).

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In addition to the technical and tactical requirements, Malwanage, Senadheera & Dassanayake and (2022) and Woodward (2013) emphasized that aerobic stamina, agility, strength, explosive power, speed, flexibility, balance, and coordination are critical components of physical fitness in badminton. Research has shown that specially selected exercises significantly improve the speed and accuracy of attacking strokes in young badminton players, underscoring the role of targeted training in enhancing performance (Shevchenko et al., 2023). Elite-level players display a superior ability to integrate visual cues from opponents' movements, enabling them to anticipate actions effectively and outperform lower-level competitors (Abdullah et al., 2023). Furthermore, badminton is distinguished by the shuttlecock's extreme speed during elite matches, where it can exceed 250 km/h (Abián et al., 2017). Alongside its physical demands, the sport involves a high level of perceptual-motor performance, tactical acumen, and psychological resilience in competitive scenarios (Arnando et al., 2023; Hülsmüller et al., 2021; Jaworski & Žak, 2016; Munzert et al., 2008). Given these complexities, evaluating game activities during tournaments is crucial for advancing high-level performance. Players must perform rapid directional changes, lunges, jumps, and arm movements, requiring significant postural adjustments (Nugroho et al., 2022; Nugroho et al., 2021; Özgür & Hotaman, 2020; Rusdiana et al., 2021). Recent research has highlighted the significant association between the Medial Longitudinal Arch (MLA) and static balance in recreational badminton players, emphasizing the importance of considering foot structure in performance enhancement (Han et al., 2022). Key skills in badminton include stroke play and footwork, which rely heavily on hand-eye coordination and balance, respectively (Woodward & Williams, 2017). Effective footwork entails quick directional changes, precise acceleration or deceleration, and enhanced shot accuracy (Ferrauti et al., 2013). Navigating the six court zones (frontcourt, midcourt, backcourt, and lateral zones) involves diverse stepping techniques, lunges, and arm motions (Wang et al., 2024). As such, agility in footwork is a central focus in training and competition (Gusliandi et al., 2020; Pratama, et al., 2024).

Over time, badminton has undergone significant transformations, highlighting the importance of performance analysis as an integral part of training programs. These analyses provide athletes with critical insights for improving their skills. For example, the modern scoring system, which requires players to achieve 21 points in two sets, assigns points for each successful stroke and penalizes unforced errors (UEs). Coaches and sports scientists thus analyze match-related performance metrics to inform tactical and technical training strategies. Technical skills, including reducing UE and increasing winner points (WPs), are crucial markers of a player's proficiency (Barreira & Chiminazzo, 2020). Hughes and Bartlett (2002) state that WPs and UEs are the primary metrics for assessing technical competence. UEs are particularly prevalent among players who lose high-level matches (Laffaye, Phomsoupha & Dor, 2015). For them, UE and WP are the leading performance metrics that change depending on the qualities of players in badminton matches. Blomqvist, Luhtanen & Laakso (1998) highlighted that analyzing a match's technical elements, particularly UEs and WPs, is critical to understanding player performance.

Prior research has consistently shown that players who lose matches, regardless of gender, nationality, or performance level, tend to commit more UEs than WPs (Abian-Vicen et al., 2014; Abián et al., 2013).

Although many studies have examined WPs and UEs as performance indicators in badminton, detailed analyses of specific skills like hitting ability, footwork, and error points across various player categories still need to be included. This gap is particularly evident among younger or beginner-level athletes, where the relationship between these skills and match outcomes is poorly understood. Despite the acknowledged importance of balance and footwork for high-level badminton performance (Malwanage, Senadheera & Dassanayake, 2022), existing research has yet to explore how age and gender influence these critical metrics comprehensively.

The study aims to investigate the influence of age and gender on smashing skills, footwork, and error points, analyze the interaction between these factors on performance metrics, and identify the age and gender groups that demonstrate optimal performance to inform tailored training programs for young athletes in Indonesia.

Materials and Methods

Participants

This study employed a purposive sampling method to recruit 24 participants from the Wincorp badminton organization in Surakarta, Indonesia. The inclusion criteria required participants to meet the following conditions: (1) be a member of the Wincorp organization, (2) have a minimum of three years of playing experience, (3) fulfil predetermined anthropometric criteria, and (4) fall within the age range of 9 to 14 years. The participants were then divided into three distinct age categories based on their developmental stage: (1) early-age players (9–10 years), (2) children's-age players (11–12 years), and (3) beginner-age players (13–14 years). Each group consisted of 8 participants, ensuring equal representation across the categories. Data collection occurred over two months, from 15 September to 16 November 2023, during which participants were observed and evaluated to assess the influence of their characteristics on badminton performance. Data collection in this study was conducted following the Declaration of Helsinki and received approval from the University Ethics Committee.

Research Design

The study utilized a quantitative descriptive research design to explore the relationship between athlete characteristics (such as age and gender) and specific performance metrics in badminton. The research focused on three primary performance variables: smash skills, footwork, and error points (unforced errors). These variables were selected based on their relevance to badminton performance and their established role in evaluating player skills. The design was chosen to provide a clear, structured assessment of how individual characteristics influence these key aspects of the sport.

Variables Observed

The primary variables observed in this study were:

Smash and Hitting Skills: This category included techniques such as smash, lob, netting, drive, underhand, drop shot, and serve. These skills were assessed based on their execution and effectiveness during match play.

Footwork Performance: Footwork was evaluated in terms of agility, court coverage, and the ability to change direction quickly and effectively.

Error Points (Unforced Errors): These were defined as mistakes made by the players that led to points being awarded to the opponent. Unforced errors were recorded and analyzed to measure the players' technical proficiency and decision-making during play.

These variables were chosen because they are widely recognized as core elements of badminton performance and are essential for evaluating players' skill levels.

Data Collection

Data were collected through direct observations of participants during regular training and match play. During the two-month data collection period, each participant was observed multiple times to ensure a comprehensive and accurate assessment of their performance in the targeted areas: smash skills, footwork, and error points.

Statistical Analysis

Data analysis was performed using SPSS version 26. Descriptive statistics were first applied to summarize the participants' characteristics and the performance metrics across the three age groups. This included calculating the mean and standard deviation for each observed variable. To determine whether there were significant differences in performance between the groups based on age and gender, a Multivariate Analysis of Variance (MANOVA) was conducted. MANOVA was chosen because it allows for the simultaneous analysis of multiple dependent variables, which reduces the risk of Type I errors when assessing the effect of age and gender on performance (Finch, 2016).

Before conducting MANOVA, assumptions of multivariate normality, homogeneity of variance-covariance matrices (verified using Box's M test), and the absence of multicollinearity were tested to ensure the validity of the results. Following MANOVA, post hoc analyses using Tukey's test were performed to identify specific group differences when significant results were obtained. The significance level for all statistical tests was set at $p < 0.05$, and effect sizes (e.g., partial eta squared) were reported to provide further context on the magnitude of observed differences. This methodological approach was designed to provide a rigorous analysis of the impact of athlete characteristics on badminton performance, ensuring that the findings were both statistically valid and practically meaningful.

Results

Table 1 below presents the average values of the variables observed in the early age (9-10 years), children (11-12 years), and beginners (13-14 years) categories, as well as in the gender category.

As shown in Table 1, the average number of smash shots, lob shots, netting shots, drive shots, underhand shots,

drop shots, service actions, and footwork was higher for early-aged athletes (aged 9–10 years) compared to children (10–11 years) and beginners (12–13 years). This trend was consistent regardless of the athlete's age category.

When the sample size ($N = 8$) includes four males and four females in each group, early-aged athletes displayed fewer average error points (7.00 for males and 8.50 for females) than children (14.00 for males and 22.50 for females) and beginners (13.25 for males and 15.00 for females). Based on gender, male athletes exhibited higher average numbers of smashes, lob shots, netting shots, drive shots, underhand shots, drop shots, service actions, and footwork than female athletes. Furthermore, male athletes consistently had fewer error points than their female counterparts (refer to Table 1 for detailed statistics).

Two critical assumptions must be verified before conducting a MANOVA test: normality and homoscedasticity (Finch & French, 2013). These assumptions were tested to determine whether they were satisfied using appropriate statistical procedures. Multivariate normality for MANOVA was evaluated using the Mardia (Korkmaz, Goksuluk & Zararzi, 2014; Oppong & Agbedra, 2016). According to the results presented in the Levene test table, all observed variables follow a multivariate normal distribution, as the p-values for both kurtosis and skewness were greater than 0.05 ($p > 0.05$). Additionally, the assumption of homogeneity of variances was tested using the Levene test. The results in the following table confirm that this assumption was also met, providing the necessary validation for performing the MANOVA analysis.

The homogeneity of variance test results, conducted using the Levene test on the variables of smash, lob, drive, underhand, and drop shots, revealed p-values > 0.05 . Therefore, the homogeneity of variance assumption was met for these five of the nine variables tested. This suggests that the assumptions for these variables are valid, as their loading values are greater than 0.05. In contrast, netting shots, serve strokes, footwork, and error points had p-values < 0.05 , indicating that the homogeneity of variance assumption was not satisfied for these variables.

The MANOVA significance test was performed to assess the effect of athlete age and gender on seven types of badminton strokes, footwork, and error points. However, it is recommended that the MANOVA significance test be conducted in both simultaneous and partial stages (Soc & Anderson, 2017).

Since not all homogeneity assumptions were validated, we relied on Pillai's Trace to perform the MANOVA test and obtain significant results simultaneously. Based on the simultaneous test results, it was found that the effects of age (F-Statistic = 15.577 $>$ F-table = 3.554), gender (F-Statistic = 27.869 $>$ F-table = 4.413), and their interaction (F-Statistic = 7.784 $>$ F-table = 3.554) were statistically significant, with each p-value being $0.000 < 0.05$. This indicates that age, gender, and the interaction between age and gender significantly influence the seven types of strokes, footwork, and error points in badminton matches across the three categories studied. The adjusted R^2 value for each model or observed variable was > 0.900 , suggesting that the MANOVA model demonstrates a high validity and goodness-of-fit (Ozili, 2023).

A partial test was conducted to determine whether a significant relationship exists between the independent and

Table 1. Mean values of variables based on age and gender categories

Variable	Age	Mean				SD	
		Male	n	Female	n	Male	Female
Smashing shot skill	Early age	14.25	4	11.00	4	1.25	1.15
	Children	24.00	4	13.25	4	1.82	1.89
	Beginner	49.75	4	23.25	4	5.37	3.20
Lob shot skill	Early age	41.75	4	39.00	4	2.21	1.15
	Children	44.00	4	55.00	4	6.73	1.63
	Beginner	72.50	4	58.75	4	10.40	7.36
Netting shot skill	Early age	20.25	4	20.25	4	1.25	1.70
	Children	18.75	4	22.50	4	3.77	3.31
	Beginner	31.50	4	26.75	4	3.78	17.55
Drive shot skill	Early age	28.75	4	26.00	4	1.25	.816
	Children	32.00	4	26.00	4	3.74	3.82
	Beginner	40.25	4	22.25	4	2.21	2.75
Underhand shot skill	Early age	18.00	4	19.00	4	2.44	1.15
	Children	21.25	4	22.50	4	1.25	2.38
	Beginner	35.75	4	23.75	4	3.30	3.94
Dropshot shot skill	Early age	13.50	4	14.25	4	1.00	1.50
	Children	29.00	4	23.75	4	9.66	3.86
	Beginner	55.50	4	36.75	4	5.44	4.78
Serving shot skill	Early age	39.00	4	38.75	4	.816	.957
	Children	39.75	4	39.25	4	2.62	3.20
	Beginner	40.25	4	38.75	4	3.30	2.36
Footwork shot skill	Early age	274.50	4	221.75	4	6.40	7.04
	Children	331.00	4	339.75	4	66.87	15.77
	Beginner	636.75	4	450.25	4	28.12	15.52
Error shot Point	Early age	7.00	4	8.50	4	1.41	.577
	Children	14.00	4	22.50	4	3.55	2.38
	Beginner	13.25	4	15.00	4	2.75	4.08

Table 2. Levene's test for equality of error variances

Variables	Levene's.	df1	df1	p-values	Description attributed
Smash shot	2.514	5	18	0.068	Assumption verified
Lob shot	2.698	5	18	0.055	Assumption verified
Netting shot	5.582	5	18	0.003	Assumption not valid
Driving shot	2.062	5	18	0.118	Assumption verified
Underhand shot	2.452	5	18	0.073	Assumption verified
Drop shot	2.636	5	18	0.059	Assumption verified
Serving shot	7.279	5	18	0.001	Assumption not valid
Footwork	5.430	5	18	0.003	Assumption not valid
Error Point	3.613	5	18	0.019	Assumption not valid

Test the null hypothesis that the error variance of the dependent variable is equal across groups. A. Design: Age + Gender + Age * Gender

dependent variables of interest or how the different groups/categories performed on the evaluated variables. If the F-test statistic exceeds the F-table and the p-value is < 0.05 , the independent variable significantly affects the dependent variable. The partial test results are presented in Table 3, showcasing the MANOVA approach's findings.

Based on the results presented in Table 3 above, athlete age significantly affects smash shots, lob shots, drive shots, underhand shots, drop shots, footwork, and error points in badminton matches. This suggests differences in the number of smashes, lob shots, drive shots, underhand shots, drop shots, footwork, and error points across the early-aged,

child-aged, and beginner-aged athlete categories. However, after analyzing all the data, we found that athlete age does not significantly affect netting and serving strokes in badminton matches. Thus, the number of netting and serving strokes within the group categories is similar.

Athlete gender also significantly affects the number of smashes, drive shots, underhand shots, drop shots, footwork, and error points in badminton matches. This indicates differences in these performance metrics between male and female athletes. However, as shown in the table, athlete gender does not significantly affect lob and netting shots. It serves in badminton matches, as the p-values for these

Table 3. Multivariate Tests

	Effect	Value	F	Hypothesis df	Error df	Sig.
Age	Pillai's Trace	1.854	15.577	18	22	.000
	Wilks' Lambda	.002	27.288 ^b	18	20	.000
	Hotelling's Trace	93.054	46.527	18	18	.000
	Roy's Largest Root	86.597	105.841 ^c	9	11	.000
Gender	Pillai's Trace	.962	27.869 ^b	9	10	.000
	Wilks' Lambda	.038	27.869 ^b	9	10	.000
	Hotelling's Trace	25.082	27.869 ^b	9	10	.000
	Roy's Largest Root	25.082	27.869 ^b	9	10	.000
Age* Gender	Pillai's Trace	1.729	7.784	18	22	.000
	Wilks' Lambda	.015	7.936 ^b	18	20	.000
	Hotelling's Trace	15.993	7.997	18	18	.000
	Roy's Largest Root	11.823	14.451 ^c	9	11	.000

a. Design: Age + Gender subjects + Age* Gender subjects

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level

Table 4. Profile of Partial MANOVA Test

Factor/Effect	Variable	F-Statistic	F-table	P
Age	Smashing shot	151.107	3.554	.000
	Lob shot	36.188	3.554	.000
	Netting shot	3.432	3.554	.055
	Driving shot	4.186	3.554	.032
	Underhand shot	38.939	3.554	.000
	Drop shot	77.345	3.554	.000
	Service shot	0.177	3.554	.839
	Footwork	189.173	3.554	.000
	Error Point	29.905	3.554	.000
Gender	Smashing shot	133.898	4.413	.000
	Lob shot	0.558	4.413	.465
	Netting shot	0.011	4.413	.916
	Driving shot	65.925	4.413	.000
	Underhand shot	9.256	4.413	.007
	Drop shot	13.178	4.413	.002
	Service shot	0.574	4.413	.458
	Footwork	36.370	4.413	.000
	Error Point	12.295	4.413	.003
Interaction or Relationship	Smashing shot	34.485	3.554	.000
	Lob shot	8.510	3.554	.003
	Netting shot	0.618	3.554	.550
	Driving shot	17.833	3.554	.000
	Underhand shot	16.777	3.554	.000
	Drop shot	7.295	3.554	.005
	Service shot	0.149	3.554	.863
	Footwork	20.466	3.554	.000
	Error Point	4.213	3.554	.032

variables were greater than 0.05. Therefore, the number of lob, netting, and service shots is similar between male and female athletes.

The interaction between athlete age and gender significantly affects the variables studied in badminton matches. This means differences exist in the number of smashes, lob shots, drive shots, underhand shots, drop shots, footwork, and error points when considering the interaction between age and gender. However, the interaction between age and gender does not significantly affect netting and serving strokes. Therefore, it can be stated that the number of netting and serving strokes remains similar across age and gender interactions.

Following the MANOVA test, a Multiple Comparison Test using the Tukey test was performed to identify the age and gender categories of athletes who demonstrated the best badminton hitting skills, footwork, and error points. Notations with different alphabets indicate statistically significant differences in the observed variables between the groups tested (i.e., age and gender categories).

The information presented in Table 5 represents the SPSS output from the multiple comparison test based on age categories. The data collected and analyzed show significant differences in the number of smashes, lob shots, drive shots, underhand shots, drop shots, footwork, and error points across the early-age (9-10 years), child-age (11-12 years), and beginner (13-14 years) athlete categories. Specifically, beginner athletes (13-14 years) performed the best and scored significantly higher in smashes, lobs, drives, underhand shots, drop shots, and footwork. On the other hand, early-age athletes (9-10 years) recorded the lowest error points.

The number of netting and serving strokes across the early-age, child-age, and beginner categories was not significantly different. This is reflected in the similar notations assigned to these groups: (20.250 a) for early-age players, (20.625 a) for child-age players, and (20.125 a) for beginner athletes.

Significant differences were also observed in the gender-based comparison analysis. Male athletes outperformed

Table 5. Results of multiple comparison tests based on age and gender distribution

Model	Age	Notation	Gender	Notation
Smash shot	Ealy age group	12.625 ^a	Female	15.833 ^a
	Children group	18.625 ^b		29.333 ^b
	Beginner group	36.500 ^c	Male	
Lob shot	Ealy age group	40.375 ^a	Female	50.916 ^a
	Children group	49.500 ^b		52.750 ^a
	Beginner group	65.625 ^c	Male	
Netting shot	Ealy age group	20.250 ^a	Female	23.167 ^a
	Children group	20.625 ^a		23.500 ^a
	Beginner group	20.125 ^a	Male	
Driving shot	Ealy age group	27.375 ^a	Female	24.750 ^a
	Children group	29.000 ^{ab}		33.667 ^b
	Beginner group	31.250 ^b	Male	
Underhand shot	Ealy age group	18.500 ^a	Female	21.750 ^a
	Children group	21.875 ^b		25.000 ^b
	Beginner group	29.750 ^c	Male	
Drop shot	Ealy age group	13.875 ^a	Female	24.916 ^a
	Children group	26.375 ^b		32.667 ^b
	Beginner group	46.125 ^c	Male	
Service shot	Ealy age group	38.875 ^a	Female	38.916 ^a
	Children group	39.500 ^a		39.667 ^a
	Beginner group	39.500 ^a	Male	
Footwork	Ealy age group	248.125 ^a	Female	337.250 ^a
	Children group	335.375 ^b		414.083 ^b
	Beginner group	543.500 ^c	Male	
Error Point	Ealy age group	7.750 ^a	Female	11.416 ^a
	Children group	14.125 ^b		15.333 ^b
	Beginner group	18.250 ^c	Male	

*. The mean difference is significant at the .05 level.

female athletes in the number of smashes, drive shots, underhand strokes, and drop shots, demonstrating superior footwork, as shown in Table 5. Male athletes received the lowest error points (7.750 a). However, there were no significant differences between male and female athletes in the number of lob shots, netting shots, and serves, as these values were similar across both gender categories.

Discussion

In this study, we investigated the influence of athlete characteristics on smashing skills, footwork, and error points in badminton matches. The analysis targeted early-aged players (9–10 years), children (11–12 years), and beginners (13–14 years). Significant differences were identified in most performance metrics across age and gender categories, offering valuable insights into developmental and physiological factors influencing badminton performance. Previous research suggests inexperienced badminton players exhibit longer contact times and smaller foot strike angles during lunges than skilled players (Lam et al., 2018).

Our findings corroborate this observation, as significant differences in footwork performance were observed across age groups. For instance, beginner athletes scored higher in footwork metrics (543.500) compared to children (335.375) and early-aged players (248.125). Male athletes

also outperformed female athletes in footwork, with average scores of 414.083 and 337.250, respectively. These results highlight the critical role of age and gender in developing footwork skills, which are essential for success in badminton. Future research should explore how biomechanical factors, such as joint angles and reaction times, contribute to these differences. The observed gender differences in performance align with earlier studies reporting higher injury risks among female athletes, particularly knee injuries in sports requiring rapid directional changes (Dugan, 2005; Stevenson et al., 1998). Our findings indicate a significant performance gap between male and female athletes, linked to individual traits evaluated using predetermined criteria, such as error points, footwork, and smashing skills. Recognizing the inherent differences between males and females, including greater loading rates and superior performance metrics among male subjects, is essential. These differences might be influenced by additional factors, such as speed, initial foot strike patterns, and contact times (Breine et al., 2019).

Male athletes exhibited lower loading rates on lob shots in the children's category than female athletes, with average rates of 44.00 and 55.00, respectively. Interestingly, no significant difference was found in netting shots among early-aged players (mean = 20.25 for both groups), while underhand shots were better performed by females, except in the beginner category. One plausible explanation is the difference in movement planes and tested parameters. The primary objective of this study was to employ MANOVA to assess how age affects badminton smashing abilities, footwork, and error points. The results revealed a significant impact of age, supported by a high F-statistic value (15.577), exceeding the F-table value (3.554), and p-values below 0.05. Gender differences also significantly influenced smashing, footwork, and error points, as indicated by an F-statistic of 27.869 (higher than the F-table value of 4.413). These findings align with the research of Putra et al. (2020), which emphasizes the influence of bio-motor conditions on movement patterns and the critical role of age in bio-motor maturity. In badminton, mastering techniques such as the forehand smash depends on proper movement patterns and bio-motor maturity, which are strongly age-dependent (Kusnandi, Asmawi & Tangkudung, 2019; Widiastuti et al., 2019). Therefore, the development of movement patterns is inevitably influenced by age and gender differences.

Our results confirm that the smash technique is one of the most effective methods for scoring points in badminton, as it allows athletes to produce high shuttlecock speeds (Putra et al., 2020). By identifying age and gender categories associated with optimal performance in smashing skills, footwork, and error points, this study provides evidence-based insights. For instance, multiple comparison tests based on age distribution revealed significant differences between males and females, such as 15.833 for females and 29.333 for males (see Table 5). Conversely, no significant differences were found in lob shots, netting shots, or serving shots based on age or gender. However, a notable disparity emerged in driving strokes, underhand shots, drop shots, footwork, and error point performance, emphasizing the influence of individual characteristics on badminton proficiency.

These findings highlight the value of statistical analysis in identifying performance determinants in badminton. Five of the nine variables tested demonstrated strong correlations

with individual characteristics, as shown in Table 2 (Levene test results). Further research should investigate the interplay of biomechanical and physiological factors to deepen our understanding of age- and gender-related differences in badminton performance. This study contributes to the growing body of evidence emphasizing the importance of tailoring training programs to the unique needs of different athlete demographics.

This study's findings are limited by its relatively small sample size and focus on a specific population of young athletes from a single badminton organization, which may not represent the broader badminton community. Additionally, the exclusion of biomechanical and psychological factors and the reliance on observational data limit the depth of analysis regarding performance mechanics. Expanding future research to include more diverse populations and advanced assessment techniques would provide more comprehensive insights.

Conclusions

The study demonstrates that age and gender significantly shape key badminton performance metrics, such as smashing skills, footwork, and error points. Beginner athletes (13–14 years) consistently outperformed younger groups, while male athletes performed more in most categories than their female counterparts.

These findings underscore the importance of developing tailored, age- and gender-specific training programs that address athletes' unique needs and developmental stages. Coaches and sports scientists can optimize skill development and enhance competitive performance by implementing targeted interventions, such as improving footwork efficiency in younger players or reducing error rates among female athletes.

However, future studies with larger and more diverse samples and advanced biomechanical and psychological assessments are needed to deepen the understanding of these influences and further refine training strategies.

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Conflicts of Interest

The authors declare no conflicts of interest.

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Визначення впливу віку та гендеру на ключові показники результативності в бадмінтоні

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 10 с., 5 табл., 50 джерел.

Історія питання. Бадмінтон, ракетковий вид спорту, що набув світової популярності, вимагає технічної точності, тактичної обізнаності та виняткової фізичної підготовки. Для досягнення успішного результату критично важливими є такі навички, як виконання атакуючого удару (сמש), робота ніг та мінімізація помилок. Однак специфічний вплив віку та гендеру на зазначені показники, зокрема серед молодих гравців, залишається недостатньо дослідженим.

Мета дослідження. Це дослідження мало на меті вивчити вплив віку та гендеру на ключові показники гри в бадмінтон, включаючи вміння виконувати сמש, роботу ніг та невимуснені помилки задля визначення розвивальних та демографічних чинників, що впливають на набуття та реалізацію навичок.

Матеріали та методи. У кількісному описовому дослідженні взяли участь 24 спортсмени (віком 9-14 років) з бадмінтонної організації "Wincorp" у Суракарті, Індонезія. Учасників було згруповано за віком (9-10, 11-12, 13-14 років) та гендером, забезпечуючи рівнозначну репрезентативність. Протягом двох місяців було зібрано дані щодо виконання сמשу, високо-далекого та плоского ударів, роботи ніг та кількості помилок. Відмінності проаналізовано за допомогою описової статистики та багатовимірного дисперсійного аналізу (MANOVA), рівень значущості встановлено в межах $p < 0,05$.

Результати. Метод багатовимірного дисперсійного аналізу встановив значний віковий вплив на виконання сמשу ($p = 0,000$), роботу ніг ($p = 0,000$) та моменти помилок ($p = 0,000$), при цьому гравці-початківці (13-14 років) досягли кращих результатів за більшістю показників. Гендерні відмінності також виявились суттєвими щодо виконання сמשу ($p = 0,000$), роботи ніг ($p = 0,000$) та моментів помилок ($p = 0,003$), причому учасники чоловічої статі випереджали учасників жіночої статі в більшості категорій. Ефекти взаємодії між віком та гендером показали значущість щодо виконання сמשу та роботи ніг ($p < 0,05$). Однак жодних істотних відмінностей у виконанні ударів біля сітки та подач не спостерігалося, незалежно від віку чи статі.

Висновки. Дослідження свідчить про те, що вік і гендер суттєво впливають на показники результативності в бадмінтоні. Спортсмени-початківці (13-14 років) продемонстрували відмінні навички порівняно з молодшими групами, тоді як хлопці загалом перевершували дівчат. Отримані дані підкреслюють важливість адаптації тренувальних програм до віку та гендеру з метою оптимізації розвитку навичок та зменшення прогалин у результативності. Задля вдосконалення тренувальних стратегій необхідно провести подальші дослідження щодо вивчення біомеханічних і психологічних чинників.

Ключові слова: бадмінтон, характеристики спортсменів, вік, гендер, показники результативності, навички виконання смєшу, робота ніг.

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The Perspective of Physical Education Teachers: Challenges within the Project-Based Learning Model

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Abstract

Background. Physical Education (PE) in Indonesia encounters challenges in optimizing learning based on the progress and development of the era. The challenge is also observable through the implementation of the Project-Based Learning (PjBL) model.

Objectives. This study aimed to describe the perspectives and challenges encountered by PE teachers in implementing the PjBL model at various educational levels.

Materials and methods. This descriptive quantitative approach research used structured and unstructured questionnaire instruments, involving 28 PE teachers from elementary, junior high, and senior high schools.

Results. The findings of the study revealed that the perspectives of PE teachers on the PjBL model at the elementary school level obtained a score of 82%, while junior high and senior high schools had scores of 78% and 75%, respectively. For the indicators of understanding, implementation, and execution of the PjBL model in Q1, Q2, and Q3, the results were 93%, 82%, and 68%, respectively. Meanwhile, the encountered challenges by PE teachers in implementing the PjBL model include limited facilities and infrastructure, a lack of teacher understanding regarding the model's implementation, and insufficient time to carry out projects. Geographic factors also posed a challenge, especially for schools in remote areas.

Conclusions. In conclusion, the perspectives of PE teachers on the PjBL model are generally quite effective, but there are still various problems, so that the experiences provided by the PjBL model cannot be absorbed well by students.

Keywords: Project-Based Learning, physical education, teacher, learning model.

Introduction

Indonesia is currently encountering 21st-century challenges due to various global issues and is dealing with three main trends: (1) the ongoing Fourth Industrial Revolution, indicated by improvements in information and communication technology in the digital revolution era; (2) societal changes observed via culture, civilization, and education transformations; and (3) the rise of the creative age, perceiving information, innovation, creativity, and knowledge as valuable resources for both individuals and society (Hendra, 2021). Education primarily aims to prepare human resources to adapt and excel competitively in the era of global competition.

The role of Physical Education (PE) as the foundation and vanguard of the Indonesian nation requires serious

efforts to develop scientific knowledge, motor activities, and the character of students (Arifin, 2017). PE is thought to make a significant difference in a lot of different physical activities and movements (Mustafa & Dwiyoogo, 2020) that help children grow and develop based on their cognitive, psychomotor, and affective traits, and their character development (Yuliawan, 2016).

Essentially, PE learning are always physical activities that give students meaningful teaching and learning opportunities and help them understand the needs, benefits (Abduljabar, 2014), and lifelong learning opportunities that come with being physically healthy (Firmansyah, 2011). PE within the national education program serves as a comprehensive learning process that encompasses all aspects of education (Mustafa, 2022). The underlying reason is the rapid societal changes and growth, requiring that PE lessons, teaching models, and methods need to improve and keep up with the era (Prasetyo & Hamami, 2020; Santika et al., 2022).

PE is expected to make a significant contribution to children's development not only intellectually and psychomotorically through movement but also in terms of personality development, particularly regarding character (Yuliawan, 2016). This responsibility lies heavily on educators to provide appropriate and effective stimuli, which significantly influence students' cognitive, affective, and motor development. Changes in the learning process impact the stimuli provided by teachers to students. Additionally, the teaching designs created by teachers profoundly affect learning outcomes.

The generational shifts and demands of the times present unique challenges and skills for PE teachers to optimize students' abilities. Applied teaching models must provide meaningful learning experiences for students, focusing on intellect, character, and physical activity. Across educational levels, educators have applied various PE teaching models, including cooperative learning, sports education, and teaching games for understanding. However, thorough research on several other teaching models is still pending (Arufe-Giráldez et al., 2023).

Currently, PE learning predominantly focuses on sports techniques. Consequently, it is unsurprising that students' interest in PE diminishes over time, and they become less active in subsequent school years. For both boys and girls, the choice of teaching materials and styles often fails to provide meaningful and socially relevant experiences (Hardman, 2010). Field observations indicate that many PE teachers do not fully utilize teaching syntax, methods, or strategies, leading to unstructured learning processes for students.

Fostering enjoyable learning environment strategy design and teaching models are important for students. This underscores the need to adapt and utilize effective models that enhance students' understanding of PE materials and movements. PE teachers must revisit and refine their teaching designs. Despite the availability of various teaching models, many PE teachers still employ monotonous approaches (Khairuddin et al., 2023). Limited capacity to develop and implement diverse teaching models remains a significant issue in providing quality PE instruction (Putra & Sepriadi, 2022).

PE curriculum, which includes the "Merdeka Curriculum" and its predecessors, focuses on turning knowledge into activities that are focused on the students, rather than activities that are focused on the teacher (Priyambudi et al., 2023; Sudrahat et al., 2022). "Merdeka Curriculum" allows educators to tailor high-quality learning experiences that align with students' needs and environments (Masturi, 2023; Mujiburrahman et al., 2023). It emphasizes active student participation to foster engagement and provide opportunities for students to develop and optimize their creativity and potential.

However, the role of PE remains underutilized by some teachers. Evaluations of PE teaching activities indicate suboptimal outcomes, with most teachers relying on teacher-centered approaches rather than student-centered ones (Putra & Sepriadi, 2022). (Sumardi et al., 2020) revealed that 59.17% of elementary school teachers use teacher-centered approaches, while only 40.83% adopt student-centered processes. Furthermore, 59.17% still employ conventional methods lectures and note-taking, whereas only 40.83% utilize techniques oriented toward higher-order thinking development.

Current PE teaching models have yet to address the various issues within PE instruction effectively. In many secondary schools, PE teachers continue to rely on conventional methods, resulting in unremarkable sports skills and learning experiences for students (Khairuddin et al., 2023).

Materials and Methods

Study Participants

This research involved male teachers teaching physical education (PE) at various educational levels in East Java, Indonesia. The selected subjects were useful to identify the perceptions and direct experiences of teachers regarding the implementation of the Project-Based Learning (PjBL) model. The research participants consisted of 28 PE teachers from various types of educational institutions: 11 teachers from elementary schools, 12 teachers from junior high schools, and 5 teachers from senior high schools. By involving teachers from different educational levels, the research provides a comprehensive overview of PjBL implementation at the PE level in the region. Data collection in this study was conducted following the Declaration of Helsinki and received approval from the University Ethics Committee.

Study Organization

This descriptive quantitative approach research provides a comprehensive overview of teachers' actual perceptions. The researchers collected information to reveal objectively the real portrays of the implementations of Project-Based Learning (PjBL) model, such as the teachers' perspectives, problems, and limitations. This research involved male teachers teaching physical education (PE) at various educational levels in East Java, Indonesia. The selected subjects were useful to identify the perceptions and direct experiences of teachers regarding the implementation of the Project-Based Learning (PjBL) model. The research participants consisted of 28 PE teachers from various types of educational institutions: 11 teachers from elementary schools, 12 teachers from junior high schools, and 5 teachers from senior high schools. By involving teachers from different educational levels, the research provides a comprehensive overview of PjBL implementation at the PE level in the region.

Statistical Analysis

Data analysis in this research includes: data reduction, data display, and conclusion drawing. The researchers began the process by collecting data through questionnaires, analyzing the data to create a data display, reducing the data in the form of narrative text to provide a clear and detailed description. The final step was to draw conclusions, where the results of the data display analysis were useful to strengthen the obtained findings, and to formulate research conclusions.

Results

Table 1 presents a compilation of survey results from each education level, from elementary to high school.

Table 1. The Implementations of PjBL at Various School Levels

Subjects		Q ₁	Q ₂	Q ₃	Σ Q ₁ -Q ₃	$\bar{x} \pm SD$	%
Primary School	Sample 1	2	3	3	8	2.67 ± 0.6	1.00
	Sample 2	2	1	1	4	1.33 ± 0.6	0.50
	Sample 3	2	3	2	7	2.33 ± 0.6	0.88
	Sample 4	2	3	3	8	2.67 ± 0.6	1.00
	Sample 5	2	3	3	8	2.67 ± 0.6	1.00
	Sample 6	2	2	1	5	1.67 ± 0.6	0.63
	Sample 7	2	3	2	7	2.33 ± 0.6	0.88
	Sample 8	2	2	1	5	1.67 ± 0.6	0.63
	Sample 9	2	3	3	8	2.67 ± 0.6	1.00
	Sample 10	1	2	2	5	1.67 ± 0.6	0.63
	Sample 11	2	3	3	8	2.67 ± 0.6	1.00
	Σ	21	28	24	73	2.21 ± 0.69	0.82
Junior High Schools	Sample 12	2	3	3	8	2.67 ± 0.6	1.00
	Sample 13	2	3	1	6	2.00 ± 1.0	0.75
	Sample 14	2	2	2	6	2.00 ± 0.0	0.75
	Sample 15	2	3	3	8	2.67 ± 0.6	1.00
	Sample 16	2	3	3	8	2.67 ± 0.6	1.00
	Sample 17	2	2	2	6	2.00 ± 0.0	0.75
	Sample 18	2	2	2	6	2.00 ± 0.0	0.75
	Sample 19	2	2	2	6	2.00 ± 0.0	0.75
	Sample 20	2	2	2	6	2.00 ± 0.0	0.75
	Sample 21	2	3	3	8	2.67 ± 0.6	1.00
	Sample 22	1	2	1	4	1.33 ± 0.6	0.50
	Sample 23	1	1	1	1	1.00 ± 0.0	0.38
	Σ	22	28	25	75	2.08 ± 0.64	0.78
Senior High Schools	Sample 24	2	3	1	6	2.00 ± 1.0	0.75
	Sample 25	1	1	1	3	1.00 ± 0.0	0.38
	Sample 26	2	3	3	8	2.67 ± 0.6	1.00
	Sample 27	2	3	1	6	2.00 ± 1.0	0.75
	Sample 28	2	3	2	7	2.33 ± 0.6	0.88
	Σ	9	13	8	30	2.00 ± 0.85	0.75

The information includes how PE teachers understood the PjBL learning model idea, how they generally used the PjBL learning model PE, and how they particularly used the PjBL learning model in large ball games. These various indicators serve as a basis for providing a comprehensive assessment of PE teachers' perspectives in understanding the PjBL learning model.

PE Teachers' Perspective toward the PJBL Model

Results on the primary or elementary level obtain a mean of 2.21 with the deviation standard of ± 0,69 and the score percentage of 82 %, indicating a 'very excellent' perception category toward PjBL model. The score distributions of the junior high school and senior high school have the mean scores of 2.08 and 2 with SD values of ±0,64 and ± 0,85. The score percentages show 78 % and 75 %, indicating an

Table 2. Achievement indicators of understanding, implementation, and PjBL model implementation

Question	Σ	$\bar{x} \pm SD$	%
Q1.	52	1,86 ± 0,36	0,93
Q2	69	2,46 ± 0,69	0,82
Q3	57	2,04 ± 0,84	0,68

excellent category of the PE teachers' perceptions toward the PjBL model.

Indicators of Understanding, Implementation, and PjBL Model Implementation

Mean score for question 1, about how excellent PE teachers understand the Project-Based Learning (PjBL) model, is 1.86, with a standard deviation (SD) of 0.36 and

Table 3. Challenges and Implementations of PjBL encountered by PE Teachers

Subjects	Q ₄	Q ₅
Sample 1	Limited facilities and infrastructure	Previous learning often used problem-based learning methods.
Sample 2	Lack of understanding regarding the PjBL (Project-Based Learning) model	Learning innovation
Sample 3	Facilities and infrastructures	Different teaching activities
Sample 4	Limited facilities and infrastructures	Learning innovation
Sample 5	Limited facilities and infrastructure	Over time, a decline in students' interest in physical education
Sample 6	Diverse student backgrounds make the PjBL model less suitable for our institution, as most students come from rural areas.	Feeling curious to try and implement different teaching models than before.
Sample 7	Facilities and infrastructures	To improve students' talents
Sample 8	Facilities and infrastructures	Feeling curious
Sample 9	Encountering no challenges	Fostering joyful learning atmosphere
Sample 10	Having no ideas about PjBL	Trying new things
Sample 11	No challenges	To encourage students' learning interests
Sample 12	Taking longer time while using PjBL	Improving students' experience, creativity, critical thinking, and empathy.
Sample 13	Having no ideas what products to produce	Using smartphone as the media
Sample 14	Passive students	Trying new learning strategies to avoid classroom-boredome
Sample 15	No challenges	Being more aware toward students' developments while using PjBL
Sample 16	Inadequate facilities	Easy to use
Sample 17	Facilities and infrastructure present challenges, and students often struggle to comprehend assigned projects, necessitating additional guidance.	Encourage curiosity in students to foster creativity and imagination freely.
Sample 18	Time constraints due to other activities leave insufficient time for implementing the model.	Training students to think creatively
Sample 19	Limited understanding of the PjBL model	Innovation and variation in learning
Sample 20	Time constraints arise due to the school's hilly geographic location, limited funding, and challenging students to guide.	Assessing students' engagement and foster critical thinking
Sample 21	PjBL requires significant time to complete a project, delaying content coverage.	Through the process, teachers can monitor students' progress, from planning to execution and final outcomes.
Sample 22	Challenges in execution and lack of understanding regarding the PjBL model	None
Sample 23	Limited understanding about PjBL model	None
Sample 24	A very short learning duration	Materials needed to teach
Sample 25	Having no ideas about PjBL model	Nothing to do related to PjBL
Sample 26	Inadequate facilities and infrastructures	To enhance collaboration among students in solving problems using their cognition and skills
Sample 27	To enhance collaboration among students in solving problems using their knowledge and skills	Our school is a "driving school" implementing the Merdeka Curriculum, where student outcomes are project-based. Project-based learning unconsciously shapes students to become more critical, creative, and communicative, fostering effective collaboration with peers and teachers.
Sample 28	The need for specific training for students lacking basic techniques or foundational knowledge in a sport requires step-by-step guidance.	Active learning process

a percentage of 93 %. Based on this assessment, PE teachers' conceptual understanding of the PjBL model across various school levels falls into the "very excellent" category. Answer

to question 2 shows how the PjBL model is being used in PE classes. It has a mean score of 2.46, a standard deviation of 0.69, and an overall percentage of 82 %. This indicates

that PE teachers have not fully implemented the PjBL model across various school levels. Question 3 reveals that various school levels have not fully applied the PjBL model to the “large ball” material. The percentage for Q₃ stands at 68%, with an average score of 2.04 and an SD of 0.84.

Challenges of PE Teachers in applying PjBL Model

PjBL learning model dealt with a lot of problems, such as inadequate facilities and infrastructure found from 9 of the 28 samples 1, 3, 5, 7, 8, 16, 17, 20, and 26. These constraints include a lack of facilities such as technological devices, suitable spaces, and other infrastructure needed to support the implementation of PjBL. In addition, a lack of understanding of the concept and application of PjBL is also a significant problem, reflected in several respondents, such as samples 2, 10, 13, 19, 22, 23, and 25. This reflects the need for training and guidance for teachers so they could understand and apply the learning model. Time constraints are also a challenge, either due to limited learning time, as in sample 24, or because the PjBL process takes a considerable amount of time, as in samples 12 and 21. Geographical factors, such as schools located in remote areas, exacerbate these time constraints. Another challenge is the presence of passive students or difficulties to direct students, as seen in samples 14 and 20. This requires a more effective approach to engage students in the learning process.

Discussion

Most of the understanding and application of the project-based learning (PjBL) model by PE teachers at various school levels show excellent results. This suggests that traditional teaching models no longer limit learning processes. Adding project-based learning models to constructivist education could facilitate students learn in the 21st century by giving them real-world examples in the form of projects (Estrada Oliver et al., 2020). The PjBL model encourages students to investigate and collaborate in developing and creating projects that reflect their knowledge (Bell, 2010).

However, PE teachers encountered challenges in implementing the PjBL model thus requiring special attention. Most research samples show that limited time, space, and facilities are big problems when trying to create different teaching models, such as PjBL (Simonton et al., 2021). Because of these problems, the learning model needs to change and fit the school setting while keeping the main parts of PjBL, such focusing on the student, allowing them explore issues in projects, learning in small groups, focusing on mastery, and choosing useful content for the students (Liu et al., 2010; Simonton et al., 2021; Webster et al., 2011).

Learning models serve as the foundation for educators to prepare teaching activities (Muthmainnah et al., 2022). They can act as tools to enhance students' abilities during the learning process (Haerullah & Hasan, 2017). As its name suggests, a learning model helps with learning by having specific features that make sense, such as naming, logical sequencing, organization, and meeting the learner's needs. It is a guideline for planning classroom- or tutorial-based learning (Trianto, 2007). Furthermore, learning models systematically outline the achievement of learning objectives, helping students reach specific goals within a structured framework.

The PjBL model offers detailed, comprehensive, and challenging learning experiences, with the project target being a product or creation. This contrasts with traditional learning models, which prioritize achieving short-term curriculum targets in a rapid and straightforward manner. Project-based learning uses problems to gather and integrate new knowledge based on real-life experiences through concrete activities. (Haerullah & Hasan, 2017) designed the PjBL model to address complex issues through investigation and understanding.

The primary goal of the project-based learning model is to focus students on developing solutions to complex problems. This requires investigation, understanding through inquiry, and guidance in collaborative projects integrated into curriculum materials (Purnomo et al., 2022). This allows students to design content using experimental and collaborative methods, fostering meaningful learning experiences. The most critical component in teaching and learning activities is the inclusion of well-structured learning models that align with PE objectives and student learning outcomes. It is essential to design learning models that suit the characteristics, needs, and demands of the times, ensuring systematic application and development (Prasrihamni et al., 2022).

Generational changes and the demands of the times pose annual challenges requiring specific skills for PE teachers to optimize student potential. The implementation of meaningful learning models must encompass intellectual, character, and physical aspects. Various studies highlight that PjBL is an effective methodology for teaching children to solve real-world problems by encouraging active participation in learning processes (Borroni et al., 2021). Systematically, PjBL models are very helpful for teaching physical education at all levels of schooling (Carrera Moreno, 2016; Coyne et al., 2016; Gubacs, 2004; Hastie et al., 2017). They facilitate students develop personal values, skills, teamwork, and motivation, among other things (Ramírez et al., 2017). For future development, providing PE teachers with training in instructional PjBL skills is critical, as research findings reveal that many PE teachers lack knowledge and understanding of the PjBL model.

Conclusions

Despite PE teachers having positive perceptions of the implementation of the project-based learning (PjBL) model, several challenges hinder its application. At the elementary school level, teachers' perceptions of PjBL fall into the “very excellent” category with a percentage of 82%, while at the middle and high school levels, perceptions are categorized as “excellent,” with percentages of 78% and 75%, respectively. Teachers' understanding of the PjBL concept is excellent, with 93% indicating a high level of comprehension. However, the application and execution of this model remain limited, particularly in certain subjects, such as team sports, where the implementation rate is 68%. Primary obstacles in applying PjBL include limited facilities and infrastructure, insufficient teacher understanding of the model implementation, and inadequate time to carry out projects optimally. Geographical factors also pose challenges, especially for schools in remote areas. Another issue is the difficulty of engaging students, who are sometimes passive or challenging to direct. To enhance the effectiveness of PjBL implementation, providing additional training for teachers, improving facilities and infrastructure, and making adjustments to time management in the learning process are important.

Conflict of Interest

The authors declare that they have no conflicts interests.

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Погляд вчителів фізичного виховання: Труднощі в рамках використання моделі методу проєктів в навчанні

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 7 с., 3 табл., 34 джерела.

Історія питання. Фізичне виховання (ФВ) в Індонезії стикається із проблемами оптимізації навчання, ґрунтуючись на прогресі та розвитку епохи. Труднощі також спостерігаються через впровадження моделі навчання з використанням проєктів (НВП, метод проєктів в навчанні).

Мета дослідження. Це дослідження мало на меті описати перспективи та виклики, що постають перед вчителями фізичного виховання у процесі впровадження моделі НВП на різних рівнях освіти.

Матеріали та методи. У цьому дослідженні застосовано описовий кількісний підхід із використанням інструментів для проведення структурованого та неструктурованого анкетування, в якому взяли участь 28 вчителів фізичного виховання, які викладають у початковій, середній та старшій школі.

Результати. Результати дослідження показали, що перспективи вчителів фізичного виховання щодо використання моделі НВП на рівні початкової школи отримали оцінку 82 %, тоді як у середній та старшій школі — 78 % та 75 % відповідно. За показниками розуміння, впровадження та реалізації моделі НВП у першому, другому та третьому кварталах результати становили 93 %, 82 % та 68 % відповідно. Водночас, серед проблем, з якими зіткнулися вчителі фізичної культури під час впровадження моделі НВП є обмеженість можливостей та інфраструктури, відсутність у вчителів чіткого розуміння щодо впровадження моделі, а також недостатній час для реалізації проєктів. Географічні фактори також становили проблему, особливо для шкіл у віддалених районах.

Висновки. Підсумовуючи, можна зазначити, що перспективи використання моделі НВП вчителями фізичного виховання загалом досить ефективні, проте досі спостерігаються численні проблеми, через які досвід, набутий в рамках впровадження моделі НВП, не може бути належним чином засвоєний учнями.

Ключові слова: навчання з використанням проєктів, фізичне виховання, вчитель, модель навчання.

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Enhancing Lower Limb Strength in Amateur Soccer Players: Assessing the Impact of Repeated Sprint Training in Tactical Soccer Drills

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

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Abstract

Background. Soccer is one of the most popular sports worldwide, including among amateur players. However, many training programs still rely on traditional methods that separate physical conditioning, technical skills, and tactical drills, limiting their effectiveness. The limited research on holistic training approaches, especially regarding lower limb strength evaluation, underscores the need for training interventions based on physiological principles.

Objectives. This study aimed to examine the effectiveness of Repeated Sprint Training (RST) in enhancing lower limb strength in amateur soccer players.

Materials and methods. Thirty-six amateur soccer players with an average age of 20 years were randomly assigned to either the intervention group (RST) or the control group (CTRL). The training program lasted four weeks, with three sessions per week. Lower limb strength was assessed using the body weight squat test and the Nordic hamstring curl test. Data analysis included the Shapiro-Wilk test, Paired t-test, and Independent t-test, conducted using SPSS 29.0.

Results. The RST group showed a significant improvement in performance on the body weight squat test (pre-test: 66 ± 8.60 ; post-test: 76 ± 6.84 , $p < 0.001$) and the Nordic hamstring curl test (pre-test: 4 ± 1.18 ; post-test: 7 ± 1.41 , $p < 0.001$). Meanwhile, in the control group, no substantial improvements were observed.

Conclusions. This study concludes that Repeated Sprint Training effectively enhances lower limb strength, particularly in the hamstring muscles. The findings of this study not only contribute to a deeper understanding of soccer player training, but also have implications for the broader field of sports science. This training method can be a practical approach to improving performance and preventing injuries in amateur soccer players, and its effectiveness could potentially be applied to other sports and athletic training programs.

Keywords: repeated sprint training, lower limb strength, amateur soccer players.

Introduction

The advancement of soccer has made it one of the most popular sports across various levels, including amateur players (Griffin et al., 2020; Woods et al., 2023). The number of soccer enthusiasts continues to grow, reflecting the high public interest in the sport (Buyrukoğlu et al., 2023; van Haaften, 2019). However, in the training process, many coaches and sports practitioners still implement traditional training models, especially for amateur players (Bozkurt, 2018; Errama et al., 2024). These training models often focus on separately

improving physical conditioning, technical skills, and tactics, limiting their effectiveness in enhancing player performance. Therefore, a holistic training approach is needed to optimize amateur players' physical development and skill acquisition (Kusuma et al., 2024). Despite this, in-depth research on training methods that precisely measure lower limb strength is still lacking. The importance of these physiological assessments, including muscle strength response, ensures that training objectives are effectively met and prevent injuries, which are common among soccer players.

A common issue experienced by soccer players, both amateur and professional, is hamstring injuries (Al Attar & Husain, 2023; Rosado-Portillo et al., 2021). These injuries frequently occur when players perform sprinting and rapid directional changes. Hamstring injuries often result in pro-

longed absences and increase the risk of re-injury if proper rehabilitation and muscle strengthening are not conducted (Al Attar & Husain, 2023; Javier Raya-González Luis Suarez-Arrones & Villarreal, 2021). Amateur players tend to have a higher risk of hamstring injuries than professionals due to a lack of structured physical training programs and limited injury recovery protocols (Zhou, 2022). Previous studies Madison et al. (2019) and van der Horst et al. (2015) have shown that hamstring muscle weakness is a key risk factor for soccer players. Amateur players frequently experience hamstring injuries during high-intensity training sessions or matches, where muscle fatigue becomes a primary trigger (Huygaerts et al., 2020). Therefore, training programs that focus on strengthening the lower limbs and hamstrings are crucial for reducing injury risk and improving player performance (Al Attar & Husain, 2023; Chebbi et al., 2022). In the current scenario, soccer training requires a speed-strength-based program incorporating eccentric exercises (Alarcón et al., 2021).

This study aims to examine the effectiveness of a training program based on Repeated Sprint Training (RST) in enhancing lower limb strength in amateur soccer players. RST is a training approach that emphasizes repeated short sprints with brief recovery periods, which are expected to improve hamstring strength and optimize player performance during matches. The findings of this study are expected to contribute valuable insights for coaches and sports practitioners in designing more effective training programs for amateur soccer players.

Materials and Methods

Study Participants

This study involved 36 amateur soccer players with an average age of 20 ± 0.86 years, body weight of 68 ± 3.24 kg, height of 171 ± 3.05 cm, and BMI (kg/m^2). The participants were randomly divided into two groups: the first group underwent the repeated sprint training (RST) intervention. In contrast, the second group received only standard training as the control group (CTRL). Participants were assessed using the lower body weight squat test and the Nordic hamstring curl test. Before the intervention, each participant had to complete an informed consent form to indicate their agreement to participate in the study. Data collection in this study was conducted following the Declaration of Helsinki and received approval from the University Ethics Committee.

Study organization

This study employed an experimental two-group pre-test and post-test design. The training program lasted four weeks, with a frequency of three sessions per week (Monday, Wednesday, and Friday). Participants' heart rate (HR) was monitored during each training session using a Polar H-10 device.

The Squat Test. In this study, baseline data collection for all groups was conducted one day before the intervention. Before testing, the researcher explained the purpose and correct execution of the body weight squat test. Participants then performed light stretching and warm-up exercises to prevent injuries. The squat test required participants to stand upright with feet shoulder-width apart, knees slightly bent,

and arms extended forward or placed on the waist. They then lowered their body until their thighs were parallel to the ground, maintaining a straight back and distributing their weight evenly on both feet. After reaching the lowest position, they returned to the initial upright stance and repeated the movement continuously until muscle fatigue occurred (Mackenzie, 2008).

The Nordic Hamstring Curl Test. Baseline data collection was also conducted one day before the intervention. The researcher explained the purpose and correct execution of the Nordic hamstring curl test. Participants performed light stretching and warm-up exercises beforehand to prevent injuries. During the test, participants knelt on a mat upright while an assistant secured their ankles. Their arms were crossed in front of the chest, and they slowly lowered their body forward before returning to the starting position in a controlled manner. This movement was repeated as many times as possible until muscle fatigue was reached. Once the participants could no longer maintain the movement, they could release their hands onto the mat to prevent injury (Matthews et al., 2015).

Statistical Analysis

The Shapiro-Wilk test was used to assess data normality. If the data were normally distributed, a paired t-test was conducted to analyze within-group differences over time. A Wilcoxon test was applied to non-normally distributed data. An independent t-test was performed to compare differences between groups. All statistical analyses were conducted using SPSS 29.0.

Results

Table 1 presents the baseline characteristics of all participants ($n = 36$), divided into two groups: the Repeated-Sprint Training (RST) group ($n = 18$) and the Control group ($n = 18$). The participants in both groups had an average age of 20 years. The mean body weight was 67.61 ± 3.12 kg for the RST group and 67.50 ± 3.45 kg for the Control group. The average height recorded was 168 cm for the RST group and 161 cm for the Control group. Additionally, both groups had an average of 7 years of soccer training experience before participating in the study.

Table 1. Characteristics of Participant

Characteristics Participant	All Participant (n = 36)	
	RST (n = 18)	Control (n = 18)
Age (years)	20 ± 0.87	20 ± 0.87
Body Weight (Kg) (mean $\pm$ SD)	67.61 ± 3.12	67.50 ± 3.45
Body Height (cm)	168 ± 2.59	161 ± 3.51
length of time for soccer practice (years)	7 ± 1.26	7 ± 1.29

Figure 1 above shows the pre-squat results with a mean value of 66 ± 8.60 and the post-squat results with a mean value of 76 ± 6.84 in the experimental group. The pre-squat and post-squat values showed a significant difference in the experimental group, with a significance value of $p < 0.001$. Meanwhile, in the control group, the pre-squat results had

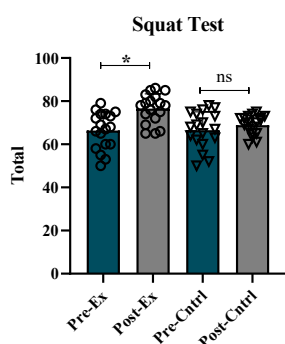


Fig. 1. Result in Paired t-test on the squat test

a mean value of 67 ± 8.47 , and the post-squat results had a mean value of 69 ± 4.49 . However, no significant difference was observed in this group, with a significance value of $p = 0.080$.

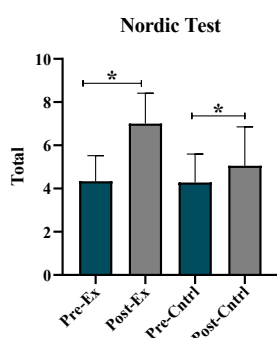


Fig. 2. Result in Paired t-test on Nordic test

Figure 2 above shows that the pre-nordic test had a mean value of 4 ± 1.18 , while the post-nordic test had a mean value of 7 ± 1.41 in the experimental group. A significant difference was observed in the experimental group, with a significance value of $p < 0.001$. In the control group, the pre-nordic test had a mean value of 4 ± 1.31 , and the post-nordic test had a mean value of 5 ± 1.79 , with a significance value of $p = 0.013$.

Table 2. Results of Independent t-test

Variable	Group	T	Sig.
Squat	RST - Control	3.943	<0.001*
Nordic test	RST - Control	3.607	<0.001*

Note: * significant results in Independent t-test

Table 2 presents the results of the Independent t-test, which analyzes the differences in squat and Nordic test performance between groups. The findings indicate a statistically significant difference in both tests. The squat test showed a T value of 3.943 with a p-value < 0.001 , while the Nordic test recorded a T value of 3.607 with a p-value < 0.001 . These results suggest that the training intervention had a meaningful impact on improving lower limb strength, as reflected in the squat and Nordic test performances.

Discussion

This study examined the impact of repeated sprint training (RST) on lower limb strength in amateur soccer

players. The primary findings of this study indicate that RST effectively enhances lower limb strength in amateur soccer players, as evidenced by improvements in body weight, squat test, and Nordic hamstring curl test results.

The present study found a significant increase in strength following this training method, as indicated by the bodyweight squat test results. These findings suggest improved neuromuscular adaptation, as evidenced by the enhanced squat test performance, which allows the muscles to function more efficiently during acceleration and sprint movements. Additionally, increased lower limb strength, as reflected in the body weight squat test, is associated with improved hip and knee stability. Previous research has indicated that players with excellent stability are less prone to injuries during on-field activities (Bliven & Anderson, 2013). Furthermore, an increase in squat repetitions has been linked to a higher rate of force development, a key factor in athletic performance (Martínez-Valencia et al., 2015). Previous studies have also demonstrated that greater propulsion force in the lower limbs is associated with more efficient and rapid acceleration at high speeds during gameplay (Wdowski & Gittoes, 2020).

Beyond improvements in lower limb strength through the bodyweight squat test, a particularly noteworthy finding of this study is that RST enhances hamstring strength in amateur soccer players, as evidenced by the Nordic hamstring curl test. This increase in hamstring strength can be attributed to eccentric contractions throughout the training. These eccentric contractions take place when the muscle undergoes tension during sprinting phases and abrupt stops, enabling rapid knee extension control. Delvaux et al. (2020) also highlighted that eccentric movement-based training improves hamstring flexibility. Similarly, Wan et al. (2021) reported that players with greater flexibility can withstand significant tension without experiencing muscle strain. The benefits of enhanced hamstring strength in amateur soccer players extend beyond injury prevention to improved on-field performance (Aktuğ et al., 2018). Alarcón et al. (2021) further stated that players with greater eccentric strength exhibit more stable sprinting mechanics and optimized movement control during rapid changes in direction. Therefore, integrating this training method into amateur soccer conditioning programs can contribute significantly to hamstring strengthening while reducing the risk of injuries frequently encountered by amateur players.

This study demonstrated that the RST method enhances lower limb strength, as evidenced by improvements in squat and Nordic test results. It significantly increases speed endurance capacity, indirectly contributing to a higher sprint frequency among amateur players. The study also reported a significant correlation between the strength of the quadriceps, hamstrings, and gluteus maximus—key muscle groups involved in the squat and Nordic test performance. Furthermore, neuromuscular adaptations (Behm et al., 2025; Ruas et al., 2018) facilitate faster motor unit recruitment during this training, enabling players to perform more squats with improved movement efficiency. Other studies have shown that squat and Nordic exercises promote hypertrophy in the quadriceps muscles, remarkably increasing the volume of the vastus lateralis (Santos et al., 2020), vastus intermedius, rectus femoris, and vastus medialis, as well as hamstring muscles such as the biceps

femoris, semitendinosus, and semimembranosus. This hypertrophy contributes to the growth of type IIa muscle fibers (EARP et al., 2015; Kubo et al., 2019; Oliver et al., 2024; Ribeiro et al., 2023). Such adaptations occur due to the repetitive concentric and eccentric contractions involved in squat and Nordic movements, which enhance tendon stiffness (Brar et al., 2021). Additionally, squat and Nordic exercises improve quadriceps and hamstring endurance, mitigating fatigue (D'Emanuele et al., 2021; Madison et al., 2019) and enhancing muscle elasticity, connective tissue integrity, and reflex potentiation (Mackey & Kjaer, 2017). Consequently, RST contributes to improved endurance performance in soccer and enhances strength training effectiveness through optimized muscular and neuromuscular adaptations (Behm et al., 2025; Huygaerts et al., 2020; Iga et al., 2012).

Conclusions

This study concludes that repeated sprint training (RST) significantly enhances lower limb strength in amateur soccer players. The eccentric-based training incorporated within RST has been proven effective in promoting neuromuscular adaptations, strengthening the hamstring muscles, and improving hip and knee stability. Furthermore, this training method presents an effective strategy for preventing hamstring injuries, which amateur soccer players frequently experience due to a lack of structured strength training programs.

Conflict of Interest

The authors declare that they have no conflicts of interests.

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Підвищення силових якостей нижніх кінцівок у футболістів-аматорів: Оцінка впливу повторних спринтерських тренувань у тактичних футбольних вправах

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 6 с., 2 табл., 2 рис., 34 джерела.

Історія питання. Футбол є одним з найпопулярніших видів спорту в усьому світі, в тому числі серед гравців-аматорів. Однак чимало тренувальних програм досі ґрунтуються на традиційних методах, які відокремлюють фізичну підготовку, технічні навички та тактичні вправи, що обмежує їхню ефективність. Обмеженість досліджень щодо комплексних тренувальних підходів, особливо стосовно оцінки силових якостей нижніх кінцівок, підкреслює необхідність проведення тренувальних інтервенцій, заснованих на фізіологічних принципах.

Мета дослідження. Це дослідження мало на меті вивчити ефективність проведення повторних спринтерських тренувань (ПСТ) щодо підвищення силових якостей нижніх кінцівок у футболістів-аматорів.

Матеріали та методи. Тридцять шість футболістів-аматорів, середній вік яких становив 20 років, було розподілено за методом рандомізації до інтервенційної групи (ІГ) або контрольної групи (КГ). Тренувальна програма тривала чотири тижні і включала три заняття на тиждень. Оцінювання сили нижніх кінцівок проводилося за допомогою тесту на присідання із вагою власного тіла (без використання додаткового обтяження) та скандинавського тесту на згинання підколінного сухожилля. Аналіз даних включав критерій Шапіро-Вілکا, t-критерій для парних вибірок та t-критерій для незалежних вибірок, що проводився із використанням програмного забезпечення SPSS 29.0.

Результати. Група ПСТ продемонструвала значне покращення показників у виконанні тесту на присідання із власною вагою (перед початком тестування: $66 \pm 8,60$; після тестування: $76 \pm 6,84$, $p < 0,001$) та скандинавському тесті на згинання підколінного сухожилля (перед початком тестування: $4 \pm 1,18$; після тестування: $7 \pm 1,41$, $p < 0,001$). Водночас у контрольній групі суттєвих поліпшень не спостерігалось.

Висновки. Дослідження показало, що повторні спринтерські тренування значно покращують силові якості нижніх кінцівок, зокрема, м'язів підколінного сухожилля. Результати цього дослідження не лише сприяють глибшому розумінню тренувального процесу футболістів, але й мають певний вплив на розвиток спортивної науки в ширшому контексті. Запропонований метод тренування може слугувати практичним підходом до поліпшення результативності та запобігання травматизму у футболістів-аматорів, а його ефективність можна потенційно застосовувати до інших видів спорту і програм спортивної підготовки.

Ключові слова: повторне спринтерське тренування, сила нижніх кінцівок, футболісти-аматори.

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Developing Students' Movement Independence: Internalizing Physical Literacy in Project-based Physical Education Learning

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Abstract

Background. This study examines the urgency of developing students' movement independence through internalizing physical literacy in physical education learning according to Project-Based Learning (PBL).

Objectives. The study aimed to explore the impact of internalizing physical literacy in physical education learning according to PBL on students' movement independence.

Materials and methods. The method used was a quantitative approach with a pseudo-experimental design, involving students of State Aliyah Madrasah Barito Kuala Regency, grade XI as the population. The sample consisted of two treatment classes (XI-A and XI-B) and two control classes (XI-C and XI-D), each with 40 students. The research instrument was a movement independence questionnaire, which was divided into 4 indicators: 1) responsibility, 2) initiative, 3) confidence, and 4) problem solving. The data analysis technique used the analysis of variance (ANOVA) to compare the results between the treatment and control classes.

Results. The findings showed that the indicators of responsibility and confidence had a very significant difference between the experimental group and the control group, with a Sig. (2-tailed) = 0.000 < 0.05 on both indicators. In the initiative and problem solving indicators, there was no substantial difference between the experimental group and the control group, with a Sig. (2-tailed) values of 0.894 and 0.062 > 0.05 respectively. Overall, the experimental group provided better results than the control group. The results indicated that the application of PBL to physical literacy internalization significantly increased students' movement independence, especially in the indicators of responsibility and confidence.

Conclusions. The conclusion of this study confirms that the internalization of physical literacy in physical education learning according to PBL is effective in increasing students' movement independence.

Keywords: movement independence, physical literacy, project-based learning.

Introduction

Physical education is one of the important disciplines in developing students' character and skills. In this context, physical literacy becomes a crucial concept to be understood and internalized by students. Physical literacy includes the

ability to move with motivation, confidence and competence, as well as an understanding of the importance of physical activity in everyday life (Cairney et al., 2019). In an era where sedentary life style is increasing, understanding and developing physical literacy is vital.

However, many students face challenges in developing movement independence. Research shows that a lack of practical experience in movement and an inability to explore different physical activities can hinder their development of independence (Vorotilkina et al., 2022). Traditional approaches to physical education learning often do not

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provide space for students to innovate and experiment with different movements (Becheva & Vakilov, 2015). One approach that can overcome this problem is Project-Based Learning (P-BL). P-BL encourages students to be actively involved in the learning process through P-BL that is relevant to their lives. By involving students in P-BL that requires movement skills, it is expected that they can internalize physical literacy values and increase their movement independence (Coyne et al., 2016).

In implementing P-BL, students not only learn physical skills, but also understand the meaning and benefits of physical activity. Research by Widiyana, I et al., (2022) shows that P-BL contributes to the improvement of students' motor skills and their self-confidence. This is important, as more confident students tend to participate more actively in physical activities. Independence of movement is an important element in the development of physical literacy. Students who are independent in movement have the ability to take initiative in physical activities, which in turn improves their health and fitness (Kairgozhin et al., 2023). Therefore, it is important to explore how the internalization of physical literacy through P-BL can improve students' movement independence.

Although many studies have examined the relationship between P-BL and physical skills, there is still a gap in the literature exploring the influence of internalizing physical literacy in this context. This study aims to fill that gap by investigating the impact of P-BL on students' movement independence, especially in the context of physical education. In addition, factors such as teacher support, a conducive learning environment, and students' intrinsic motivation also play an important role in the development of movement independence (Vorotilkina et al., 2022). In the implementation of P-BL, the role of the teacher as a facilitator is very important to guide students in finding solutions and building skills independently.

Movement independence also includes mental and emotional aspects. Students who feel independent in movement tend to have a higher sense of responsibility towards their health. Rois & Almaulidia, (2023) showed that students who engaged in active learning had higher self-confidence and were more responsible for their physical health. By promoting physical literacy through P-BL, we not only train students' physical skills, but also build a strong foundation for movement independence (Silverman & Mercier, 2015). This research is expected to contribute significantly to the development of a more effective and engaging physical education curriculum.

This study introduces novelty by integrating the Project Based Learning (P-BL) approach specifically in physical education learning, with a focus on developing students' movement independence. Although P-BL has been applied in various educational contexts, its application in physical education and its relationship with the internalization of physical literacy has not been widely researched.

One of the theories that supports this novelty is the Self-Directed Learning Theory proposed by Loeng (Loeng, 2020). This theory emphasizes the importance of students to take initiative in their learning process, which is in line with the principles of P-BL. According to research by Husnan et al., (2023), the use of active methods such as P-BL can develop physical literacy and increase student participation

in physical activity. In addition, research by Exkwantri et al. (Exkwantri et al., 2023) shows that P-BL can improve student learning outcomes. However, this study will delve deeper into how the implementation of P-BL can facilitate the development of students' movement independence, complementing previous research that has not explored this relationship specifically.

With this approach, it is hoped that this research can make a significant contribution to the development of a physical education curriculum that is more innovative and responsive to students' needs. The results of this study are also expected to inspire educators to implement more interactive and effective methods in physical education learning, so that students can be better prepared to face the challenges of an ever-evolving world, and become active and healthy individuals throughout their lives.

Materials and Methods

Participants

The population of this study were all students of State Aliyah Madrasah Barito Kuala Regency, South Kalimantan Province, precisely class XI consisting of 4 classes, namely class XI-A, XI-B, XI-C and XI-D. The entire population was used as a research sample or population research. The experimental class is class XI-A and XI-B and the control class is class XI-C and XI-D, each consisting of 40 students. The division of classes is done by purposive sampling because it considers the learning schedule set by the school with the assumption that the condition of students' abilities is homogeneous (Taherdoost, 2016). Data collection in this study was conducted following the Declaration of Helsinki and received approval from the University Ethics Committee.

Research Design

Type of Research, This research uses a quantitative approach with a quasi-experimental design with a control group time-series design (Leppink, 2019; Vaughn, Debbie & Lomax, 2020). The research design picture is as follows:

Treatment	T ₁	x	T ₂	x	T ₃
Control	T ₁	-	T ₂	-	T ₃

The treatment group is the group that is given the treatment of internalizing physical literacy based on the P-BL Model. The control group is a group that is treated with a direct learning model (direct instruction). Quantitative research allows researchers to measure variables statistically and test hypotheses through systematic testing.

The variables of this study consist of independent variables, namely the internalization of P-BL-based physical literacy while the dependent variable is the independence of student movement. The research instruments used in this study were questionnaires and observation sheets to measure students' movement independence. The questionnaire was designed based on the theory (Kayrgozhin et al., 2022) that movement independence is divided into indicators; 1) responsibility, 2) initiative, 3) confidence, and 4) able to solve problems.

The procedure for implementing the research through treatment to the experimental class and the control class.

The experimental class received treatment with learning to apply internalization of physical literacy based on P-BL, while the control class received learning using a direct instruction learning model. The experimental class and the control class both underwent treatment once a week with a learning duration of 3×45 minutes = 135 minutes, namely during Physical Education class hours. Treatment in the experimental class by applying internalization of physical literacy learning based on P-BL is by following the P-BL learning syntax which begins with; 1) identification of basic problems/questions, 2) project planning, 3) information collection, 4) solution development, 5) application and realization of solutions, 6) presentation of results, 7) reflection and evaluation (Helle & Olkinuora, 2020; et al., 2016). In the implementation of learning, the experimental class is integrated with the principle of physical literacy, namely the instillation of an active culture of moving routinely and continuously with high understanding and motivation and self-confidence (Lounsbury & McKenzie, 2015). The integration of physical literacy principles in learning is given to students through the stages/ syntax of the P-BL model learning, especially at the reflection and evaluation stages, at the stage the teacher investigates the stages of each student's project and provides process feedback on each learning process every week. So it is very possible that learning in the experimental class, students who understand the core material well and have high motivation and self-confidence, then students will practice the learning material again outside of class hours several times a week. While in the control class by implementing a direct instruction learning

model, namely learning that follows the following syntax; 1) delivery of learning objectives, 2) giving instructions, 3) demonstrations and directed exercises, 4) feedback, 5) conclusions and independent assignments (Yanti, 2019; Zhu & Tongdechroen, 2023). After the learning is complete, the teacher repeats the same thing by continuing the learning material the following week.

Statistical Analysis

Data analysis begins with prerequisite tests including normality and homogeneity tests to ensure that the data meets statistical assumptions. The Shapiro-Wilk test is used for normality, and the Levene test for homogeneity (Harrison et al., 2020). Data analysis tested the hypothesis using ANOVA to compare the results between the experimental and control groups. Tukey's follow-up test was used to determine specific differences between groups (Larini & Barthes, 2018).

Results

The data on student movement independence obtained by the researchers were then tested for preliminary analysis which included; 1) data normality test and 2) data homogeneity test, before testing the research hypothesis. The results of the preliminary analysis test are as follows

Table 3 shows the ANOVA test results for several indicators in the treatment and control classes, including responsibility, initiative, confidence, and problem solving. In the responsibility indicator in the treatment class, the value

Table 1. Normality Test Results of Movement Independence Data

Group		Shapiro-Wilk				
		Statistic	df	Sig.	p	Category
Treatment	Pre-test	0.955	40	0.114	0.05	Normal
	Middle-Test	0.982	40	0.761	0.05	Normal
	Post-test	0.976	40	0.531	0.05	Normal
Control	Pre-test	0.975	40	0.510	0.05	Normal
	Middle-Test	0.967	40	0.297	0.05	Normal
	Post-test	0.965	40	0.251	0.05	Normal

Table 2. Homogeneity Test Results of Student Movement Independence Data

Results		Levene Statistic	df 1	df 2	Sig.	p	Category
Independence of Movement	Based on Mean	.186	5	234	.968	0.05	Homogeneous
	Based on Median	.172	5	234	.973	0.05	Homogeneous
	Based on Median and with adjusted df	.172	5	228.199	.973	0.05	Homogeneous
	Based on trimmed mean	1.348	5	234	.245	0.05	Homogeneous

Table 3. ANOVA Test Results

Indicator	Sum of Squares	df	Mean Square	F	Sig.
Responsibility in the Treatment Class	39.650	2	19.825	3.600	0.030
Responsibility in the Control Class	1208.150	2	604.075	117.564	0.000
Initiative in the Treatment Class	94.850	2	47.425	1.771	0.175
Initiative in Control Class	0.517	2	0.258	0.084	0.920
Self-Confidence in the Treatment Class	67.200	2	33.600	3.292	0.041
Self-Confidence in Control Class	1110.650	2	555.325	79.415	0.000
Problem Solving in the Treatment Class	6.817	2	3.408	0.461	0.632
Problem Solving in the Control Class	1.517	2	0.758	0.099	0.905

Table 4. Further Test with Tukey

Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.
Responsibility in the Treatment Class	Pretest	Middle test	-1.32500*	0.52475	0.034
		Posstest	-1.07500	0.52475	0.105
	Middle test	Pretest	1.32500*	0.52475	0.034
		Posstest	0.25000	0.52475	0.883
	Posstest	Pretest	1.07500	0.52475	0.105
		Middle test	-0.25000	0.52475	0.883
Responsibility in the Control Class	Pretest	Middle test	-1.00000	0.50687	0.123
		Posstest	6.17500*	0.50687	0.000
	Middle test	Pretest	1.00000	0.50687	0.123
		Posstest	7.17500*	0.50687	0.000
	Posstest	Pretest	-6.17500*	0.50687	0.000
		Middle test	-7.17500*	0.50687	0.000
Initiative in the Treatment Class	Pretest	Middle test	-2.15000	1.15708	0.156
		Posstest	-0.77500	1.15708	0.781
	Middle test	Pretest	2.15000	1.15708	0.156
		Posstest	1.37500	1.15708	0.462
	Posstest	Pretest	0.77500	1.15708	0.781
		Middle test	-1.37500	1.15708	0.462
Initiative in Control Class	Pretest	Middle test	-0.02500	0.39227	0.998
		Posstest	-0.15000	0.39227	0.923
	Middle test	Pretest	0.02500	0.39227	0.998
		Posstest	-0.12500	0.39227	0.946
	Posstest	Pretest	0.15000	0.39227	0.923
		Middle test	0.12500	0.39227	0.946
Self-Confidence in the Treatment Class	Pretest	Middle test	-1.20000	0.71436	0.217
		Posstest	0.60000	0.71436	0.679
	Middle test	Pretest	1.20000	0.71436	0.217
		Posstest	1.80000*	0.71436	0.035
	Posstest	Pretest	-0.60000	0.71436	0.679
		Middle test	-1.80000*	0.71436	0.035
Self-Confidence in Control Class	Pretest	Middle test	-0.25000	0.59130	0.906
		Posstest	6.32500*	0.59130	0.000
	Middle test	Pretest	0.25000	0.59130	0.906
		Posstest	6.57500*	0.59130	0.000
	Posstest	Pretest	-6.32500*	0.59130	0.000
		Middle test	-6.57500*	0.59130	0.000
Problem Solving in the Treatment Class	Pretest	Middle test	-0.37500	0.60801	0.811
		Posstest	0.20000	0.60801	0.942
	Middle test	Pretest	0.37500	0.60801	0.811
		Posstest	0.57500	0.60801	0.613
	Posstest	Pretest	-0.20000	0.60801	0.942
		Middle test	-0.57500	0.60801	0.613
Problem Solving in the Control Class	Pretest	Middle test	0.15000	0.61757	0.968
		Posstest	0.27500	0.61757	0.897
	Middle test	Pretest	-0.15000	0.61757	0.968
		Posstest	0.12500	0.61757	0.978
	Posstest	Pretest	-0.27500	0.61757	0.897
		Middle test	-0.12500	0.61757	0.978

of $F = 3.600$ with $\text{Sig.} = 0.030$ indicates a significant difference between groups. Meanwhile, in the control class, the value of $F = 117.564$ with $\text{Sig.} = 0.000$ shows a very significant difference. For the initiative indicator, the experimental class obtained a value of $F = 1.771$ with $\text{Sig.} = 0.175$, which

indicates no significant difference between groups. Similar results were also seen in the control class, with a value of $F = 0.084$ and $\text{Sig.} = 0.920$. On the confidence indicator, the treatment class showed a value of $F = 3.292$ with $\text{Sig.} = 0.041$, which means there is a significant difference between

Table 5. Independent Significance Test Results

Indicator	Variants	F	Sig.	t	df	Sig. (2-tailed)
Responsibility	Equal variances assumed	3.339	0.072	14.257	78	0.000
	Equal variances not assumed			14.257	72.843	0.000
Initiative	Equal variances assumed	0.716	0.400	-0.134	78	0.894
	Equal variances not assumed			-0.134	76.851	0.894
Confident	Equal variances assumed	1.579	0.213	10.252	78	0.000
	Equal variances not assumed			10.252	75.636	0.000
Solving Problems	Equal variances assumed	0.384	0.537	1.894	78	0.062
	Equal variances not assumed			1.894	77.424	0.062

groups. On the other hand, in the control class, the value of $F = 79.415$ with $\text{Sig.} = 0.000$ shows a very significant difference. For the problem solving indicator, the results in the treatment class showed a value of $F = 0.461$ with $\text{Sig.} = 0.632$, so there is no significant difference between groups. Similarly, in the control class, with a value of $F = 0.099$ and $\text{Sig.} = 0.905$, no significant difference was found.

Overall, in the treatment class, the responsibility and confidence indicators showed significant differences, while the other indicators did not. In contrast, in the control class, responsibility and confidence showed a very significant difference, while the other indicators still did not show a significant difference. A more detailed explanation of the results can be seen in table 4.

Based on Table 4 of the Tukey test results, it can be seen that in the responsibility indicator, the experimental class showed a significant difference between the pretest and the middle test ($\text{Sig.} = 0.034$), but there was no significant difference in other comparisons. In contrast, the control class recorded highly significant differences from pre-test to post-test and from middle test to posstest ($\text{Sig.} = 0.000$). For the initiative indicator, in both the treatment and control classes, no significant difference was found at all stages ($\text{Sig.} > 0.05$). In the confidence indicator, the experimental class only showed a significant difference between the middle test and posstest ($\text{Sig.} = 0.035$), while the control class recorded a very significant increase from pre-test to pos-test and from middle test to pos-test ($\text{Sig.} = 0.000$). As for the problem-solving indicator, there were no significant changes at any stage for both classes. Overall, significant changes were more frequent in the control class than the treatment class, especially in the responsibility and confidence indicators.

Based on Table 5. The results of the independent difference test, analysis using independent samples t-test shows that the indicators of responsibility and confidence have a very significant difference between the experimental group and the control group, with a $\text{Sig. (2-tailed)} = 0.000$ on both indicators. In the initiative and problem-solving indicators, no significant differences were found between the experimental and control groups, with a Sig. (2-tailed) values of 0.894 and 0.062, respectively. The results of Levene's test show that the assumption of equal variance is accepted for all indicators, because the $\text{Sig.} > 0.05$. Thus, it can be concluded that significant changes only occurred in the indicators of responsibility and confidence, while initiative and problem solving remained consistent with no difference between the experimental and control groups.

Discussion

The results showed that the internalization of physical literacy in P-BL-based physical education learning was able to increase students' movement independence. In addition, the increase in students' movement independence is seen from the indicators; 1) responsibility, 2) initiative, 3) self-confidence, and 4) solving problems based on the ANOVA test and Tukey test, the results show that there are significant differences in the indicators of responsibility and self-confidence while the aspects of initiative and problem solving are not.

This study indicates that students who are engaged in P-BL-based learning activities are more likely to be responsible for their tasks. This is in line with the theory proposed by Azizah & Wardani (Azizah & Wardani, 2019) and Wati et al. (Wati et al., 2024) which states that experiential learning, such as P-BL, can increase student engagement and encourage them to become more independent in the learning process. Furthermore Amini et al. (Amini et al., 2019) shows that students who engage in P-BL-based learning show an increase in responsibility, as they are required to complete tasks collectively and individually. This creates an awareness of the importance of their contribution in the group, thus increasing the sense of responsibility. This confirms that innovative methods such as P-BL can have a positive impact in physical education, similar to the findings in this study.

In addition to responsibility, the aspect of self-confidence also experienced a significant increase. Students who were given the opportunity to actively participate in P-BL felt more confident in their physical and social skills. According to Hossein-Mohand et al. (Hossein-Mohand et al., 2021) and Atmono et al. (Atmono et al., 2023) P-BL-based learning allows students to adapt to challenges and tackle problems head-on, which contributes to increasing their self-confidence (Sinaga et al., 2023). When students successfully complete tasks or challenges in P-BL, they will feel more confident to face similar situations in the future.

However, there is research by Estrada Olibier et al. (Estrada Oliver et al., 2020) which shows that not all students gained improvement in movement independence when using the P-BL method. The study found that external factors such as environmental support and student readiness strongly influenced the outcomes. This highlights the importance of context in the application of this method and suggests that the effectiveness of P-BL may vary depending on certain factors, such as 1) A conducive environment also plays a role in the successful implementation of the P-BL method. Rahayu et al. (Rahayu et al., 2018) emphasizes that a positive learn-

ing atmosphere can increase student motivation. Schools should create a supportive environment for students to learn actively. 2) The use of technology in P-BL learning can increase student interaction and engagement. Sudjimat, Dwi et al. (Sudjimat et al., 2021) points out that the integration of technology in learning can expand access to information and increase student participation. 3) The development of innovative learning media is essential to support the implementation of P-BL. Further research by Syukriah et al. (Syukriah et al., 2020) and Rosiana et al. (Rosiana et al., 2023) shows that the use of appropriate media can improve student understanding and engagement. Therefore, further research needs to be done to develop media that are appropriate to the learning context. 4) In the context of physical education learning, it is necessary to include health awareness elements to build students' understanding of the importance of physical activity. Suwiwa et al. (Suwiwa et al., 2023) showed that an understanding of health can increase students' motivation to participate in physical activity. 5) Creating space for students to be actively involved in the learning process. Septaliza et al. (Septaliza et al., 2024) indicates that actively engaged students are more likely to acquire the necessary skills. 6) The most important factor is the understanding of teachers who run the P-BL model in physical education learning. Mukti et al. (Mukti et al., 2020) shows that the lack of teacher understanding of this method can hinder the effectiveness of achieving the learning objectives set.

The implications of this study are very important for the development of physical education curriculum (Hardinata et al., 2024; Harianto et al., 2023; Mariati et al., 2024). The application of the P-BL method which proved effective in increasing students' movement independence suggests that this approach should be integrated into the curriculum. This is also in line with the view of (Cairney et al., 2019) which states that physical literacy is the key to building a healthy lifestyle. Some studies also provide information that physical literacy has a good impact on active skills for students (Mashud, Arifin, et al., 2023; Mashud, Warni, et al., 2023; Mashud et al., 2024).

Based on the research results, some recommendations that can be proposed are: 1) Intensive training is needed for teachers to understand and implement the P-BL method well. This training should include classroom management techniques and relevant curriculum development. 2) The physical education curriculum needs to be updated to include P-BL elements, so that students can learn in a more active way and be directly involved in learning. 3) Further research needs to be conducted to explore the factors that influence the effectiveness of P-BL in different contexts, including student variables such as initiative, problem solving, motivation and student background.

Overall, this study provides important insights into the positive impact of implementing P-BL-based physical literacy integration in physical education learning to increase students' movement independence. It is hoped that the results of this study can serve as a reference for the development of better educational practices in the future. By implementing the recommendations provided, it is hoped that the quality of physical education in Indonesia can improve.

Conclusions

This study shows that the application of P-BL-based physical literacy internalization in physical education

learning significantly increases students' movement independence, especially in the aspects of responsibility and self-confidence. The results of the analysis showed a significant difference between the treatment and control classes, which supports the hypothesis that interactive learning methods can facilitate the improvement of students' movement independence. Although there was no significant difference in the initiative and problem-solving indicators, the findings provide insight into the importance of innovative learning approaches in physical education.

Suggestions for future research are to explore more deeply the factors that influence learning outcomes, especially on the initiative and problem-solving indicators. In addition, it is important for educators to consider the integration of technology in learning and involve parents in the educational process to create a more supportive learning environment. Thus, it is expected that students can be more motivated and actively participate in physical activities, ultimately improving their overall movement independence

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Conflict of Interest

The authors declare that they have no conflicts interests.

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Розвиток рухової самостійності учнів: Інтерналізація фізичної грамотності в процесі навчання фізичного виховання з використанням проєктів

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

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Історія питання. У цьому дослідженні розглядається актуальність розвитку рухової самостійності учнів через застосування фізичної грамотності в процесі навчання фізичного виховання за методом проєктів (навчання з використанням проєктів, НВП).

Мета дослідження. Мета дослідження полягала у вивченні впливу інтерналізації фізичної грамотності в процесі навчання фізичного виховання за методом проєктів на рухову самостійність учнів.

Матеріали та методи. У дослідженні застосовано кількісний підхід із псевдоекспериментальним дизайном, в якому учні Державної школи Медресе Алія, регенство Баріто Куала (State Aliyah Madrasah Barito Kuala Regency), XI клас, виступали в якості досліджуваної популяції. Вибірка складалася з двох експериментальних класів (XI-A і XI-B) і двох контрольних класів (XI-C і XI-D), кожен з яких налічував 40 учнів. Дослідницький інструмент — опитувальник рухової самостійності, який був розділений на 4 показники: 1) відповідальність, 2) ініціативність, 3) впевненість і 4) розв'язання задач. У методиці аналізу даних використовувався дисперсійний аналіз (ANOVA) з метою порівняння результатів між експериментальною та контрольною групами.

Результати. Отримані дані показали, що індикатори відповідальності та впевненості мають дуже значущу різницю між експериментальною та контрольною групами, при цьому двосторонній рівень значущості склав: Sig. (2-tailed) = 0,000 < 0,05 для обох індикаторів. За показниками ініціативності та розв'язання задач суттєвої різниці між експериментальною та контрольною групами не спостерігалось, при цьому Sig. (2-tailed) = 0,894 та 0,062 > 0,05 відповідно. Загалом, експериментальна група досягла кращих результатів, ніж контрольна група. Результати свідчать про те, що застосування НВП для засвоєння фізичної грамотності сприяло значному підвищенню рухової самостійності учнів, особливо за показниками відповідальності та впевненості.

Висновки. Проведене дослідження підтверджує, що засвоєння фізичної грамотності під час навчання фізичного виховання за методом проєктів є ефективним у підвищенні рухової самостійності учнів.

Ключові слова: рухова самостійність, фізична грамотність, навчання з використанням проєктів.

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Conducting a Core-Based Exercise Program in Movement Competency Training Course to Improve Pain Tolerance and Abdominal Endurance of Female University Students with Primary Dysmenorrhea

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

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Abstract

Objectives. This study aimed to examine the effect of conducting a core-based exercise program in a movement competency training course on improving pain tolerance and abdominal endurance of female university students with primary dysmenorrhea.

Materials and methods. A total of 112 qualified female university students completed the training course. It used an uncontrolled trial approach of experimental research involving three phases: a week for pre-tests and orientation; 8 weeks of movement competency training; and a week of post-tests.

Results. According to this study, a large significant decrease in menstrual pain (-55.45 %) and an increase in pain tolerance (22.54 %), muscular endurance (40.57 %), and aerobic capacity (41.60 %) was observed after the movement competency training ($p < .001$). Post-pain tolerance (kg) has a significant positive relationship with post-abdominal endurance (reps) ($\beta = 0.093$; $p < .001$) and post- $\text{VO}_{2\text{max}}$ ($\beta = 0.163$; $p < .001$). It has been demonstrated that post-pain tolerance accounts for 98.2 % of the variances in post-abdominal endurance and 98.4 % in post- $\text{VO}_{2\text{max}}$.

Conclusions. The findings indicate that a core-based exercise intervention integrated into the movement competency training course was found to be effective in reducing menstrual pain and improving pain tolerance, muscular endurance and aerobic capacity in female university students experiencing primary dysmenorrhea. A progressive core exercise program can be used as a non-pharmacological treatment for pain management and to enhance the body capacity of females with pain discomfort.

Keywords: core exercise, dysmenorrhea, PATHFIT 1, pain management, pain tolerance.

Introduction

Globally, primary dysmenorrhea afflicts a substantial proportion of women, with reported prevalence rates varying from 17 to 90 % (Ferries-Rowe et al., 2020). Particularly affecting the quality of life, primary dysmenorrhea usually causes absence from workplaces or classrooms, reduced output, and increased need for healthcare. In addition, dysmenorrhea is the most common gynecological problem that has an impact on most students in their academic performance and daily activities (Mahwish et al., 2024). The prevalence of dysmenorrhea worldwide ranges from 16 to 91 %, and 10–20 % of them suffer from severe dysmenorrhea, which is the leading cause of recurrent school absenteeism (80 %),

loss of class concentration (66.8 %), no active participation (47.4 %), inability do homework (21 %), fail in an exam (15.4 %), and limited activity (29.9 %) (Mesele et al., 2022).

Primary dysmenorrhea is postulated to arise from the synthesis of prostaglandins (Ferries-Rowe et al., 2020) during menstruation, which precipitates potent uterine contractions, diminished uterine blood flow, and subsequent activation of nociceptors. While non-steroidal anti-inflammatory drugs represent the principal therapeutic approach for this condition (Marjoribanks et al., 1996), their efficacy in providing comprehensive relief is not universal, and prolonged usage is associated with potential adverse effects. As such, non-pharmacological modalities like physical exercise are attracting more and more attention as possible supplementary therapies for primary dysmenorrhea.

Owing to the potential of exercise to augment endorphin secretion (Saaniyoki et al., 2018) and attenuate inflammation

(Gleeson et al., 2011), a multitude of studies have scrutinized its efficacy in the management of primary dysmenorrhea (Tsai, 2024). Despite this extensive investigation, the scholarly discourse remains divided regarding the most effective form of exercise (Matthewman et al., 2018; Carroquino-Garcia et al., 2019). Various modalities have been examined, encompassing relaxation exercises such as progressive muscle relaxation (Çelik & Apay, 2021) and self-administered massage (Azima et al., 2015), alongside strength training (Saleh et al., 2016), aerobic exercises (Kannan et al., 2019), yoga (Kirca & Celik, 2023), mixed exercise regimes (Kirmizigil & Demiralp, 2020), and the Kegel maneuver (Amreen et al., 2013). Certain studies have documented substantial alleviation in pain following only 4 weeks of exercise intervention (Yildiz & Acaroğlu, 2022), whereas others indicate a necessity for up to 8 weeks to discern any tangible benefits (Ortiz et al., 2015). Furthermore, the incidence of participant withdrawal has exhibited variability across these diverse exercise protocols (Çelik & Apay, 2021; Pocaan, 2023).

Supported by the abovementioned findings, this study implements a core-based exercise program integrated into movement competency training under the Physical Activity Towards Health for Fitness 1 (PATHFIT 1) course to improve pain tolerance and abdominal endurance of female university students with primary dysmenorrhea. This course is a requirement for all undergraduate students in the Philippines. The study aimed to provide effective movement-based interventions focused on core regions for female students to improve pain management and physical fitness.

Materials and Methods

Study Participants

One hundred two out of 114 first-year female university student enrollees handled by the researcher in Physical Activity Towards Health and Fitness 1 course or movement competency training course in one state university experiencing primary dysmenorrhea volunteered and completed the movement competency training. Five participants were excluded due to experiencing severe dysmenorrhea, 4 were due to their active participation in fitness clubs the previous month, and 3 had mild to severe health conditions (Figure 1). A signed informed consent form was retrieved from the participants before the start of the study, and authorization to conduct the study was also secured from the university's research committee. The study was conducted during the first semester of the academic year 2023-2024 (Table 1).

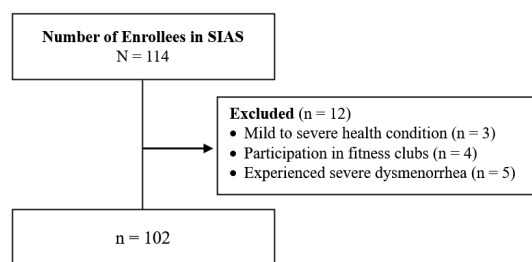


Fig. 1. Selection of participants

Table 1. Participants' anthropometrics and baseline data (n = 102)

Indicator	Average	Range
Height (cm)	150.40 ± 4.59	143-160
Weight (kg)	55.37 ± 7.01	44-68
Age (years)	19.04 ± 0.82	18-20
Menstrual pain (scale)	5.41 ± 1.19	4-7
Pain Tolerance (kg)	1.65 ± 0.32	0.99-2.07
Abdominal endurance (reps)	10.87 ± 2.65	6-15
Aerobic Capacity (VO ₂ max)	36.85 ± 3.06	31.83-41.75

Design and test procedures

The uncontrolled trial approach of experimental research involving pre- and post-tests was used. The study underwent three phases: a week for pre-tests and orientation; 8 weeks of movement competency training; and a week of post-tests. Similar procedures of field tests were used in pre- and post-tests. All the participants were instructed on the necessary warm-up and cooldown to prevent injuries and to condition the body during the test and training. Participants were instructed to avoid caffeinated and soda drinks, and heavy meals 48 hours before the post-test.

The participants were evaluated using a self-reported visual analog scale to measure the experienced menstrual pain for the last 3 months for the pre-test and a month after the training program for the post-test. The pain scoring consists of a straight line that ranges from "no pain" on the left end (0 cm) of the scale to "worst pain" on the right end (10 cm) (Delgado et al., 2018). An algometer (FPX 25 Digital Algometer, Wagner Force Ten) was used to measure the pain tolerance (kg) of the participants. In a relaxed supine position, a gradual pressure was applied using the device perpendicular to the tissue of the T12 region of the rectus abdominis (subcostal nerve) for both left and right. The application of pressure stops once the participants say "now" after they reach the maximum pain. Three applications were given for each region with 30 seconds interval to reduce wind up and three findings per region were recorded. The average of the six findings was the final score of the test.

A curl-up test was used to measure abdominal endurance (reps). Participants started by lying on their backs with knees bent and feet 12 inches from the buttocks. Without holding or resting the feet, participants extended their arms on their thighs and kept their heads neutral. Participants curled up slowly until their shoulders lifted two inches off the mat, then lowered back down, completing each curl-up in three seconds. The test continued without pauses until exhaustion. Only properly executed curl-ups—shoulders raised two inches, head off the mat, heels down, and correct timing—were counted as one score.

The aerobic capacity was evaluated using the 12-minute run test on a 50m flat surface back and forth (Pocaan, 2024). At a standing stance, the participants started to run after the command of a sharp whistle sound (Fox 40 Pealess, US), and the clock started. The participants stop running when 12 minutes have elapsed, and the total distance completed is recorded (km). The VO₂max was calculated using the formula: (22.351 x km) - 11.288. This test is valid and reliable (Cooper, 2013).

Movement competency training program

Table 2. Workout compositions

Workout	Composition	Intensity/reps
1	Plank (standard)	Hold for 20-30 seconds
	Dead bug	10-12 reps per side
	Glute bridge	15 repetitions
	Bird dog	10-12 reps per side
	Plank with shoulder taps	12-15 taps per side
2	Side plank	Hold for 20-30 seconds per side
	Russian twist	12-15 reps per side,
	Bicycle crunches	15-20 reps per side
	Mountain climbing	30 seconds
	V-ups	12-15 reps

The movement competency training program aimed to enhance core strength, endurance, and stability gradually in eight weeks. Participants participated in once-a-week training for two hours per session. It comprises foundational core exercises and integrates progression principles to challenge the body while decreasing recovery time. The initial workout includes plank, dead bug, glute bridge, bird dog, and plank with shoulder taps for stability and core activation. Meanwhile, the second workout includes dynamic and rotational movements like side plank, Russian twists, bicycle crunches, mountain climbers, and V-ups, which challenge the obliques and increase overall core strength (Table 2). A similar training was employed every two consecutive

weeks, alternating workouts 1 and 2. The training starts with 5 sets, increasing by two sets. The progressive approach of the training course gradually increases the intensity while reducing recovery and rest times (Table 3).

Statistical Analysis

Data are expressed as mean $\pm$ standard deviation for continuous variables. The Kolmogorov-Smirnov test was conducted to evaluate the distribution's normality. A paired sample t-test was employed to calculate the pre-test and post-test results. The change ratio (Δ) assessed pre-test and post-test differences. Statistical significance was established at $p \leq 0.05$. Linear regression analysis examined the relationships among the variables' post-tests. Cohen's d effect size (ES) was calculated to illustrate the magnitude of differences between variables. The statistical analysis was conducted utilizing IBM SPSS version 29.

Results

A significant difference and large effect size were observed in menstrual pain, pain tolerance, muscular endurance, and aerobic capacity after the movement competency training at $p < .001$, with -55.45 %, 22.54 %, 40.57 %, and 41.60 % improvements, respectively (Table 4).

The analysis in Figure 2 revealed that post-pain tolerance (kg) has a significant positive relationship with post-abdominal endurance (reps) ($\beta = 0.093$; $p < .001$) and post- VO_2max ($\beta = 0.163$; $p < .001$). Post-pain tolerance accounts for 98.2 % of the variances in post-abdominal endurance and 98.4 % in post- VO_2max .

Table 3. Training Course Timeline

Duration	Weeks 1-2	Weeks 3-4	Weeks 5-6	Weeks 7-8
Work out	1,2,1,2,1	1,2,1,2,1,2,1	1,2,1,2,1,2,1,2,1	1,2,1,2,1,2,1,2,1,2,1
Recovery time	20 secs.	15 secs.	13 secs	10 secs
Rest between workouts	2.5 mins.	2.25 mins.	2 mins.	1 min.

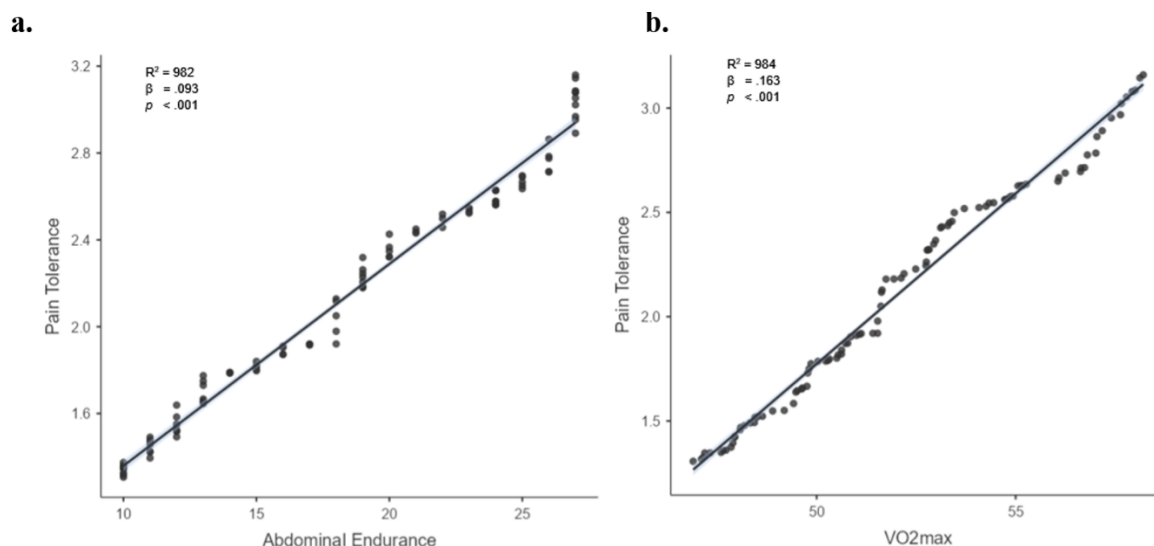


Fig. 2. (a) linear regression between post-pain tolerance (kg) and post-abdominal endurance (reps); (b) linear regression between post-pain tolerance and post- VO_2max , at $p < .001$.

Table 4. Effect of movement competency training on pain tolerance, muscular endurance, and aerobic capacity

Indicator	Pre	Post	Δ	p	ES
Menstrual pain (scale)	5.41 $\pm$ 1.19	2.41 $\pm$ 1.09	-55.45%	< .001	0.85
Pain tolerance (kg)	1.65 $\pm$ 0.32	2.13 $\pm$ 0.54	22.54%	< .001	-0.90
Muscular endurance (reps)	10.87 $\pm$ 2.65	18.29 $\pm$ 5.76	40.57%	< .001	-0.83
Aerobic capacity (VO ₂ max)	36.85 $\pm$ 3.06	52.18 $\pm$ 3.28	41.60%	< .001	-0.88

Discussion

The results of the core-based exercise program in the movement competency training course showed a significant decrease in menstrual pain and increased pain tolerance, muscular endurance, and aerobic capacity.

My findings reveal a large decrease in menstrual pain after the training course, implying the effectiveness of the course and can be used as a non-pharmacological intervention for managing primary dysmenorrhea. In an experimental study, women engaged in core exercises experienced lesser pain intensity compared with non-participation. Many laboratory experiments reveal that the decrease in menstrual pain is associated with core exercise participation since it improves blood circulation, reduces muscle tension (Verma et al., 2024), and enhances the release of endorphins or the natural painkillers of the body (Paungmali et al., 2018). Furthermore, the improved pain tolerance in the rectus abdominis region observed in my study implies that core training exercises positively influence pain thresholds which is beneficial for females to be more resilient to menstrual discomfort. It may indicate that core muscle adaptation to intense exercise can be linked to improved pain tolerance. Similarly, recent studies also revealed that core strengthening and stability exercise programs are an appropriate method for improving pain tolerance (Smrcina et al., 2022; Baiaomonte et al., 2017; López-Liria et al., 2021). An integration of planned and systematic exercise intervention in course curricula may serve as an alternative medicine for pain management and can improve the quality of life of individuals suffering from primary dysmenorrhea.

In terms of muscular endurance, my study also found a large improvement, suggesting that the intensity of the training course enhances the stamina of the core muscles. Including core training in physical education courses for women positively improves their physical performance and functionality as it reduces physical limitations caused by menstrual pain (Bağcı Çelik et al., 2024). Furthermore, core stability and muscular endurance exercises improve the physical performance metrics of women (Genc et al., 2019). The focus on progression in this training program likely contributed to the gains in endurance. The increase in VO₂ max demonstrates the course's positive influence in reducing menstrual pain and improving fitness. Enhanced aerobic capacity signifies improved blood circulation and oxygen uptake that reduces muscle tension and discomfort during menstruation, which is beneficial for overall health and pain management (Çiçek, 2018; Pocaan, 2024; Pocaan, 2023). The enhanced aerobic capacity is also beneficial for women's heart and lung health, and immune function for long-term health. It includes reducing the risk of heart disease and respiratory issues since cardiovascular diseases are a leading cause of mortality among women (Vogel et al., 2021).

The strong relationship between pain tolerance and other fitness markers implies that the increase in women's ability to pain tolerance benefits pain management and improves physical endurance and cardiovascular capacity. This also suggests that the implemented training course was suitable for improving females' capacity to manage pain and sustain core stability. My study proves that sustained exercise efforts increase pain tolerance allowing muscle adaptation for women that is necessary to endure menstrual discomfort. Enhanced pain tolerance can facilitate regular physical activity, resulting in improved cardiovascular health and core strength, both essential for long-term well-being. This finding corroborates the research conducted by Inglés & Kropotov (2019), demonstrating that exercise interventions significantly alleviate pain and enhance physical endurance in women.

Conclusions

The core-based exercise intervention integrated into the movement competency training course in my study was found effective in reducing menstrual pain and improving pain tolerance, muscular endurance and aerobic capacity in female university students experiencing primary dysmenorrhea. A progressive core exercise program can be used as a non-pharmacological treatment for pain management and to enhance the body capacity of females with pain discomfort. My study offers effective movement-based interventions focused on core regions that can be used to improve pain management and physical fitness. My findings were also consistent with the emerging research on the positive effect of exercise on pain management and functional improvement. My study supports incorporating appropriate training interventions for pain tolerance and fitness programs for improved health outcomes.

Conflict of Interest

The author declares no conflict of interest in conducting this study.

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Проведення програми на основі комплексу вправ для м'язів кора в рамках тренувального курсу з розвитку рухової компетентності щодо покращення показників толерантності до болю та абдомінальної витривалості студенток ВНЗ з первинною дисменореєю

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 7 с., 4 табл., 2 рис., 34 джерела.

Мета дослідження. Мета цього дослідження полягала у вивченні впливу проведення програми на основі комплексу вправ для м'язів кора в рамках тренувального курсу з розвитку рухової компетентності на покращення показників толерантності до болю та абдомінальної витривалості студенток ВНЗ з первинною дисменореєю.

Матеріали та методи. Загалом 112 кваліфікованих студенток ВНЗ завершили курс тренування. У роботі використувався неконтрольований метод експериментального дослідження, що включав три фази: тиждень передтестових етапів та спрямованості; 8 тижнів тренування з розвитку рухової компетентності; і тиждень післятестових етапів.

Результати. Згідно з даними цього дослідження, після проведення тренування з розвитку рухової компетентності спостерігалось значне зниження менструального болю (-55,45 %) і підвищення толерантності до болю (22,54 %), м'язової витривалості (40,57 %) та аеробної здатності (41,60 %) ($p < 0,001$). Постбольова толерантність (кг) має достовірний позитивний зв'язок з постабдомінальною витривалістю (повторення) ($\beta = 0,093$; $p < 0,001$) і поствимірюваним показником VO_{2max} ($\beta = 0,163$; $p < 0,001$). Продемонстровано, що постбольова толерантність пояснює 98,2 % варіацій постабдомінальної витривалості і 98,4 % поствимірюваного показника VO_{2max} .

Висновки. Результати дослідження свідчать про те, що інтервенція на основі комплексу вправ для м'язів кора, інтегрована у тренувальний курс з розвитку рухової компетентності, виявилась ефективною щодо зменшення менструального болю та покращення толерантності до болю, м'язової витривалості та аеробної здатності у студенток, які страждають на первинну дисменорею. Прогресивна програма вправ для розвитку м'язів кора може використовуватись

як нефармакологічний метод лікування болю та сприяти підвищенню продуктивності організму жінок, які відчувають больовий дискомфорт.

Ключові слова: вправи для м'язів кора, дисменорея, програма PATHFIT 1, лікування болю, толерантність до болю.

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Evaluating Validity and Test-retest Reliability on Indonesian Basketball Talent Scouting Model for Athletes Aged 10 to 14

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Abstract

Background. Identifying talent in young athletes is crucial for effective sports coaching. However, in Indonesia, early detection of basketball talent is often hindered by the limitations of current identification methods and tools.

Objectives. This study aimed to enhance the current aptitude test for basketball players aged 10 to 14. To assess the effectiveness of the revised model, the study evaluated its validity and test-retest reliability using data from both male and female athletes.

Materials and methods. To ensure validity, four doctoral-qualified experts and seven experienced basketball coaches with an average of 12.78 ± 2.2 years coaching experience, with a type B license and bachelor's degree in sports, evaluated the test. The test-retest reliability was assessed including 40 athletes aged 10 to 14 with an average age of 12.3 ± 1.0 years, consisting of 20 males (height 160.2 ± 1.3 cm, weight 47.5 ± 7.2 kg, average training 3.5 ± 1.12 years) and 20 females (height 157.2 ± 3.7 cm, weight 44.5 ± 6.3 kg, average training 3.2 ± 1.06 years). All participants were regional champions. The test was administered twice, with a one-week interval between sessions.

Results. The study produced three types of tests, namely anthropometry (height, weight, fat range, arm length), biomotor (endurance, strength, flexibility, speed, reaction, balance, general motion), basketball skills (dribbling, passing, shooting) with Aiken V > 0.8 validity, test-retest with a product moment correlation of $p < 0.05$ and $r = 0.786$, and independent t-test on male athletes and female athletes sig. 0.134 or $p < 0.05$.

Conclusions. The findings indicate that the talent scouting model of Indonesian basketball athletes aged 10 to 14 has proven to be valid and reliable from the aspects of anthropometric tests, biomotor tests and basketball skills tests. The ease of implementation, clarity of instructions, and security of the test also add to the advantages of this model. In addition, this model can be applied to male and female athletes without significant differences. Further research is needed to facilitate ongoing development by adding psychological tests and expanding the number of samples.

Keywords: basketball, talent scouting, talent development, basketball measurements, sports testing.

Introduction

Previous research has highlighted the importance of early talent identification in basketball. However, in Indonesia, this process is often hindered by inadequate methods and instruments (Fariz et al., 2023). Previous

research entitled "Development Assessment Model for Talent Identification of Young Indonesian Basketball Players: Anthropometrics, Biomotor, Technical, and Tactical Skills" has made a significant contribution in the development of a comprehensive assessment model (Susanto et al., 2024). While a comprehensive assessment model has been developed, it requires further refinement in terms of validity and reliability. Additionally, the validation process has relied on a limited number of coaches, and the experience level of the basketball players involved has not been clearly defined. Therefore, this study, in addition to testing the validity and

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reliability, will increase the number of large and competent samples.

Validity is an important aspect in ensuring that this assessment model is able to measure what should be measured accurately (Susiono et al., 2024; Wedi et al., 2024), while test-retest reliability is needed to determine whether the model is consistent in providing the same results when it is reapplied under similar conditions (Salafi et al., 2023). The importance of this retesting becomes particularly relevant when the model is used in young age groups that are still in a rapidly changing stage of physical and skill development. If this scouting Indonesian basketball athletes model is valid and has high reliability, coaches will be able to identify athletes' talents more accurately, understand their strengths and weaknesses, and design more effective training programs (Quílez-Maimón et al., 2023).

Based on previous literature studies, another positive benefit is that sports schools and academies will more easily select and recruit talented athletes, as well as monitor their development with measurable data, improving the school's reputation in producing quality athletes (Ribeiro Junior et al., 2021). The sports organization sector will also benefit from a more transparent and systematic talent identification process, enabling the organization to foster long-term athletes and improve team quality (Doncaster et al., 2020; Kalén et al., 2021). Then, for parents, a clear and tested talent scouting model provides clarity about their child's potential, increases confidence in the child's athletic development, and helps them provide more appropriate support (Prieto-Ayuso et al., 2017; Ribeiro et al., 2021). Overall, this model will create a better sports coaching ecosystem and improve basketball achievement in Indonesia.

In addition, to provide a more comprehensive picture, a comparison between the perception and performance of male and female athletes in using this model is needed. Previous study showed that there are physiological, biomotor, and cognitive differences between men and women that might affect the results of the aptitude assessment, which makes this test even more relevant (Han et al., 2023). By making this comparison, this study is expected to identify whether there is a need to modify the model to suit specific needs based on gender. This study aims to improve the existing talent assessment model and test the validity and test-retest reliability of basketball athletes aged 10-14, for both men and women, in order to create a more precise, accurate, and useful model for the talent coaching of basketball athletes in Indonesia.

Materials and Methods

Study Participants

The population of this study was a basketball club located in Yogyakarta Province. The sample of this study involved 11 experts as validators, consisting of four lecturers from basketball coaching with a minimum of doctoral qualifications and seven experienced basketball coaches, aged 36-40 years, have 12.8 ± 2.2 years average career as a coach, had a type B license, and had a bachelor's degree in sports. Then, 40 basketball athletes (20 male and 20 female) were selected using purposive sampling. Their characteristics included aged 10 to 14 with an average age of 12.3 ± 1.0 years. In male athletes with a height of 160.2 ± 1.3 cm, body weight of 47.5 ± 7.2 kg, the average training time is 3.5 ± 0.6 years. In female athletes with a height of

157.2 ± 3.7 cm, body weight of 44.5 ± 6.3 kg, the average training time is 3.2 ± 0.6 years. Then, other characteristics of basketball athletes were that they had participated in competitions, had been champions at the regional level, and were undergoing training for tournament events.

Study Organizations

This quantitative research aimed at measuring the effectiveness level of the model by validity test and test-retest reliability test. This study examined a model of scouting for basketball athletes in Indonesia aged 10 – 14 that has been developed by Susanto et al (2024). The first procedure was examining the results of the study Susanto et al (2024) and then modify them to match aged 10 to 14, so that the results of the study obtained anthropometry test models, biomotor tests, basketball skills tests (Table 1). Then, the research was translated into Indonesian language. The results of the translation were used during the validation assessment. The second procedure was developing a questionnaire aimed at assessing the test model. The questionnaire was answered by validators and basketball athletes for reliability testing. The third procedure was conducting a validation test followed by four lecturers and seven coaches. The validation test aimed to assess, provide input or modify the talent scouting model. After the talent scouting model was valid, the fourth procedure was followed by testing on athletes. Athletes tried a form of talent scouting test then filled out a questionnaire. Athletes ran the first test and the second test with a one-week time lag (Król-Zielińska et al., 2019; Tenelsen et al., 2019) physically active adults participated in the validity study, and 49 subjects were recruited for the reliability study. The motor task required subjects to perform two-legged drop jumps using drop heights of 24, 43, and 62 cm as well as one-legged drop jumps with the left and right leg using a drop height of 24 cm. Ground contact times were simultaneously quantified with an electronic contact mat, a force plate (i.e., gold standard; Hollstadt et al., 2020; Robinson et al., 2024), in order to optimally maintain the consistency of test results. The fifth procedure was reporting the results of research by publishing this scientific paper. Data collection in this study was conducted following the Declaration of Helsinki and received approval from the University Ethics Committee with the number B/1112/UN.34/16/PT.01.03/2024.

Assessment Questionnaire

This talent scouting model was part of the procedure in the second stage. This questionnaire was used to assess the Anthropometry test model, Biomotor test, basketball skills test on the scouting test of basketball athletes in Indonesia. Those four aspects consisted of 13 statement items: four general aspects items, three Anthropometric aspects, three Biomotor aspects items, three basketball skills items. The preparation of statement items in this questionnaire referred to the results of previous research on aptitude scouting tests (Gál-Pottyondy et al., 2021; Pino-Ortega et al., 2021) the need for data mining leads to the use of data reduction techniques such as Principal Component Analysis (PCA; Kelly et al., 2021) the selection into and successful transition out of a national talent pathway in basketball is yet to be explored. Thus, the primary aim of this study was to explore

Table 1. Design of talent scouting tests on basketball athletes aged 10 to 14

Indicator	Tests	
Anthropometric Test	Body Height	
	Body Weight	
	Fat Range: Body Fat (triceps, subscapular)	
	Arm Length	
Biomotor Test	Cardiovascular	multistage fitness test
	Strengths	push ups, sit ups, back ups, pull ups, wall sit
	Suppleness	Sit and reach
	Speed	30-meter sprint
	Reaction	Smart WBR 515-GM
	Balance	Smart Balance Test 515-JY
	General gestures	Soken / Power Ball Overhead Throw (Backwards)
Basketball Skills Test	Dribbling	Crossover Dribble and Reverse Dribble
	Passing	Chest Pass and Bounce Pass
	Shooting	Free throw

the influence of relative age, gender, and playing time based on the selection into the Regional Talent Hubs and Basketball England youth teams (U16, U18, and U20; Larkin et al., 2023) which were then converted into a statement item. The scale used in the questionnaire was 1-4: 1 for 'strongly disagree', 2 for 'disagree', 3 for 'agree', and 4 for 'strongly agree'.

Table 2. Aiken V Validity Test Results

Item	Statement	ΣS	n(c-1)	V
General				
Item 1	This test can be done in the field or at school or in a closed room	27	33	0.818
Item 2	These test instructions are easy to understand and perform	27	33	0.818
Item 3	This test is safe for athletes aged 10-14	28	33	0.848
Item 4	This series of tests doesn't take many days	28	33	0.848
Anthropometric Test				
Item 5	This anthropometric test is able to accurately measure body composition (height,29 weight, fat range, arm length)	33	33	0.878
Item 6	This anthropometric measurement is relevant in assessing the physical potential of28 young basketball athletes	33	33	0.848
Item 7	The instruments used in anthropometric tests are sufficient and up to standard	27	33	0.818
Biomotor Test				
Item 8	This biomotor test can accurately assess the physical abilities of young athletes	27	33	0.818
Item 9	This biomotor test is in accordance with the physical components needed during the28 basketball game	33	33	0.848
Item 10	This biomotor test provides clear information about the basic physical skills needed in29 basketball	33	33	0.878
Basketball Skills Test				
Item 11	This technique skill test can assess the basic ability to play basketball (dribbling, passing,28 shooting) well	33	33	0.848
Item 12	This technical skill test already covers all the basic techniques that young basketball28 players need	33	33	0.848
Item 13	The results of the technical skills test provide an accurate picture of the basic technical27 abilities of the athlete's basketball	33	33	0.818

Statistical Analysis

The data analysis in the first test was a validity test using the Aiken formula (Aiken, 1985) in Figure 1 below. The second test was a reliability test, namely test-retest. The test-retest in this study used product moment correlation by correlating the results of the first test and the second test. The third test was independent t-test, the purpose of this test was to analyze the difference in answers in male and female athletes with a value of sig. 0.05. However, before the product moment correlation analysis and independent t-test were conducted, normality test was done first if it was needed. Data analysis of this study used the help of SPSS 26.

$$V \text{ Aiken's: } \frac{\sum s}{n(c-1)}$$

S : r – lo
 Lo : lowest rating score
 C : highest rating score
 r : the score given by the assessor

Fig. 1. Aiken V Formula

Results

The results of this study showed that the first analysis was a validity test using the Aiken V formula. The validity test was carried out by 11 validators, namely four lecturers and seven basketball coaches, who assessed this talent scouting test based on the assessment questionnaire (Table 2).

Based on table 2, four aspects consisting of 13 statement items showed that the Aiken V value is >0.8 , so that the scouting test for basketball athletes in Indonesia for ages 10 – 14 years consisting of Anthropometry test, Biomotor test, Basketball Skills test was declared to have a high validity value (Aiken, 1985).

The next test was carried out by basketball athletes, 20 male and 20 female athletes, as a test-retest reliability test using product moment correlation and independent t-test. However, the normality test used Shapiro-Wilk ($p>0.05$) which showed that test value 1 was 0.093 and test 2 was 0.065, so test 1 and test 2 showed that the data were normally distributed. Then, product moment correlation was proceed as shown in Table 3 below.

Table 3. Product Moment Correlation results

		Test 2
Test 1	Pearson Correlation	0.786
	Sig. (2-tailed)	0.000
	N	40

Based on the results of Table 3, the correlation of test 1 and test 2 showed a significance value of 0.000 or $p<0.05$, and the pearson correlation value showed $r=0.786$. The test-retest results meant that there was a relationship between Test 1 and Test 2 with a correlation of 0.786. The next test was done to test the test assessment questionnaire of the talent scouting model between male and female athletes as shown in Table 4 below.

Based on the results of Table 4, the significance value was $0.05<0.134$, i.e. $p>0.05$, meaning that there was no difference in the answers of male and female athletes, aged 10-14, in Test 1 and Test 2 of the Indonesian basketball scouting test.

Discussion

Based on the results of the study, anthropmetric tests, biomotor tests, basketball skill tests resulted in a good level of validity and strong reliability. It showed that the scouting test for Indonesian basketball athletes aged 10-14 can be used for the search and scouting process of prospective basketball athletes in the future.

In the general aspect, this model showed the ease of test implementation, easy-to-understand test instructions, and a safe and simple form of test. It is important because in an early age sports environment, easy-to-implement and understandable test procedures are key in maintaining the measurement consistency and active participation of young athletes. It was explained by the results of previous research on soccer talent scouting tests in Indonesia for children aged 9 – 11, providing four types of tests such as basic ball juggling test, shuttle ball passing test, zigzag ball dribbling test,

agility run test showing high validity and reliability values (Saputra & Hadinata, 2017; Lubis et al., 2020). Simplicity in this set of tests could minimize procedural errors, both by examiners and participants, which in turn contributes to the validity and reliability of the test results. Previous research has explained that the simplicity of talent scouting tests makes athletes more serious in conducting tests, such as the talent test of tennis athletes aged 12-14 with seven test instruments (Prasetiono & Gandasari, 2018). Then, in combat sports such as talent scouting tests for pencak silat athletes aged 12 – 14, there were also three test models, namely five anthropometric tests, five physiological tests and five biomotor tests, all of which were assembled like posts that must be done by athletes (Syaifullah & Doewes, 2020). With these results, this talent scouting model deserves to be widely implemented, as it meets the basic technical requirements in athlete auditions.

The anthropometric test aspect in this model was valid and reliable in measuring the physical potential of young basketball players. Talent test research for 13-year-olds in Australia, discussed that the anthropometry of an athlete can predict the level of speed and strength ability (Larkin et al., 2023). The accuracy of anthropometric measurements such as height, arm length, and weight provides important data for coaches in assessing the physical readiness of athletes in accordance with the physical demands of basketball such as endurance, speed, agility, strength (Lu & Yin, 2022; Yılmaz, 2022; Florensa et al., 2023). Therefore, this test was relevant to the physical potential needed by a basketball player, because anthropometric factors have a significant role in determining athlete performance. In addition, anthropmetric tests on athletes from an early age can provide options for young athletes to be directed to determine the type of sport to be chosen (Kaynar & Bilici, 2019). Thus, the anthropometric tests in this model not only meet the exact measurement standards, but are also directly relevant to the potential evaluation of basketball athletes, especially in terms of physical growth that is essential for on-court performance.

In the aspect of biomotor tests, which included measurement, endurance, strength, agility, were also considered valid and reliable. The results of this test indicated that the scouting model can accurately assess the needs of important physical components in basketball matches. Biomotor tests are very important in scouting the talent of basketball athletes aged 10-14 because they can measure the basic physical abilities and potential of athletes which in turn supports performance during training or competition (Han et al., 2023). Basketball as a sport relies heavily on biomotor components such as speed and agility, making the measurement of these physical components particularly relevant for identifying athletes' potential (Susanto et al., 2023). To date, the biomotor test or physical skill test is the

Table 4. Independent T-test Results

		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Assessment Questionnaire	Equal variances assumed	1.515	78	0.134	0.875	0.577
	Equal variances not assumed	1.515	77.862	0.134	0.875	0.577

basic foundation of every basketball scouting test of every sport that requires physical ability (Abazi et al., 2023). The high validity and reliability of this test gives coaches and sports organizations the confidence that this model can be used to accurately assess an athlete's biomotor potential. In addition, talent scouting tests on team sports can also be used as a basis for the development of more specific training programs (Kalén et al., 2021).

In the aspect of basketball skill test assessment, which included the assessment of the ability of basic basketball playing techniques such as dribbling, passing, and shooting, it was considered valid and reliable. It is important because basic engineering skills are the main foundation for every basketball player (Begu et al., 2023). In addition, children aged 10 – 14 are an important time to develop advanced movement skills needed to master basic techniques such as throwing and catching (Koryahin & Hrebinka, 2023; Santoso et al., 2024). This basketball coaching test model covered all the basic techniques needed to comprehensively assess an athlete's talent, providing coaches with important insights into a player's technical ability. Some previous research studies, talent scouting tests can also be done by simply combining technical and physical skills tests such as running then shooting, passing by running, or dribbling by zig-zagging (Joseph et al., 2021; Larkin, Sanford, et al., 2023). In addition, good technical skills allow athletes to adapt more quickly to game situations, improve individual and team performance, increase motivation and confidence, and make decisions quickly (Çetinkaya et al., 2024; Djaba et al., 2024; Latief et al., 2024). The success of this test in evaluating basic technical skills validly and reliably provides a solid foundation for the selection and coaching process of young athletes who focus on mastering the fundamentals of the game.

Then, the results of this study also showed that there were no significant differences between the answers of male and female athletes in assessing this talent scouting model. It showed that the model can be applied universally to both sexes and can be used effectively to identify potential talents in both male and female athletes. It opened up wider opportunities in the coaching and development of young basketball athletes in Indonesia without gender differences (Oliveira Castro et al., 2022), as well as providing a solid basis for expanding their application at various levels of coaching. This valid and reliable talent scouting model makes it easier for coaches, basketball clubs, schools and parents of athletes to comprehensively assess the physical potential, techniques and tactics of young basketball athletes (Juita et al., 2024). Then, a deeper analysis is also needed on talent development in the training environment using the Talent Development Environment Questionnaire (TDEQ-5) especially in basketball (Putro et al., 2025). The limitation of this study is the relatively small sample size, which included athletes from basketball clubs in Yogyakarta Province. Future research should aim to develop aptitude scouting tests that incorporate psychological assessments and involve a larger sample.

Conclusion

Based on the results of the study, the talent scouting model for Indonesian basketball athletes aged 10-14 proved

to be valid and reliable in measuring the potential of athletes from the aspects of anthropometric tests, biomotor tests and basketball skills tests. The ease of implementation, clarity of instructions, and safety of the test also add to the advantages of this model, making it effective and easy to implement in an early sports environment. Every aspect of the test, namely physical tests and basketball skills tests, can be used to assess the potential of athletes with high accuracy, ensuring that this model is able to identify the talent of athletes comprehensively. In addition, this model can be applied to male and female athletes without significant differences, demonstrating its suitability for widespread use in the talent scouting process in Indonesia. Nevertheless, for the future, further development is needed by adding psychological tests and expanding the number of samples.

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Conflict of Interest

The author has no conflict of interest regarding the author or results of other studies.

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Оцінювання валідності та тест-ретестової надійності індонезійської моделі пошуку талантів у баскетболі для спортсменів віком від 10 до 14 років

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 8 с., 4 табл., 1 рис., 34 джерела.

Історія питання. Виявлення талантів у молодих спортсменів має вирішальне значення для забезпечення ефективного спортивного тренування. Однак в Індонезії розкриття талантів у баскетболі на ранньому етапі часто ускладнюється обмеженістю сучасних ідентифікаційних методів та інструментів.

Мета дослідження. Метою цього дослідження було вдосконалити існуючий тест для визначення здібностей баскетболістів віком від 10 до 14 років. Щоб проаналізувати ефективність переглянутої моделі, в дослідженні проведено оцінювання її валідності та тест-ретестової надійності, використовуючи дані як спортсменів-хлопців, так і спортсменок-дівчат.

Матеріали та методи. Задля забезпечення валідності оцінювання тесту проводили чотири експерти з докторським ступенем та сім досвідчених баскетбольних тренерів із середнім стажем тренерської роботи $12,78 \pm 2,2$ років, які мають ліцензію категорії «В» та ступінь бакалавра зі спортивних наук. Для оцінки тест-ретестової надійності було залучено 40 спортсменів віком від 10 до 14 років, середній вік яких становив $12,3 \pm 1,0$ років, до складу яких входили 20 хлопців (зріст $160,2 \pm 1,3$ см, вага $47,5 \pm 7,2$ кг, середній досвід тренувань $3,5 \pm 1,12$ років) та 20 дівчат (зріст $157,2 \pm 3,7$ см, вага $44,5 \pm 6,3$ кг, середній досвід тренувань $3,2 \pm 1,06$ років). Усі учасники дослідження були регіональними чемпіонами. Тест застосовувався двічі з тижневим інтервалом між сеансами.

Результати. У дослідженні проведено три типи тестів з метою визначення антропометричних показників (зріст, вага, рівень жирової маси, довжина рук), біомоторних (витривалість, сила, гнучкість, швидкість, реакція, рівновага, загальні рухи), баскетбольних навичок (дриблінг, передача, виконання кидків) із застосуванням коефіцієнта валідності Айкена $V > 0,8$, тест-ретесту з кореляційним моментом добутку $p < 0,05$ та $r = 0,786$, а також t-критерію незалежних вибірок для спортсменів-хлопців та спортсменок-дівчат з рівнем значущості $p < 0,05$, $0,134$ або $p < 0,05$.

Висновки. Отримані результати свідчать про те, що модель пошуку талантів індонезійських баскетболістів віком від 10 до 14 років виявилася валідною та надійною з точки зору проведення антропометричних тестів, біомоторних тестів та тестів для визначення баскетбольних навичок. До переваг цієї моделі також можна віднести простоту реалізації, зрозумілість інструкцій та безпечність тесту. Крім того, зазначену модель можна застосовувати до спортсменів і спортсменок без суттєвих відмінностей. Необхідно провести подальші дослідження з метою сприяння продовженню розвитку шляхом додавання психологічних тестів і розширення кількості вибірок.

Ключові слова: баскетбол, пошук талантів, розвиток талантів, вимірювання показників у баскетболі, спортивне тестування.

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A Comprehensive Approach to Enhancing Volleyball Skills: The Role of Problem-Based Learning, Constraint-Led Approach, and Motivation

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Abstract

Objectives. This study aimed to assess whether there is a difference in influence between Constraint-Based Problem-Solving (CBA-PBL) and PBL (Problem-Based Learning), whether there is an interaction between the PBL-CBA model and motivation, and whether there is a difference in influence between students who have high and low motivation after undergoing PBL-CBA and PBL models.

Materials and methods. The study employed an experimental method with a 2×2 factorial design, where treatment was needed, involving 40 students.

Results. The results of the study obtained the value of F count PBL-CBA (A1) and PBL (A2) = 105.144 ($p < 0.05$), thereby indicating a significant difference ($\mu A1 = 106.6 > \mu A2 = 100.4$). Fcount interaction PBL (A)*motivation (B) = 280.779 ($p < 0.05$), thus there is a substantial interaction. A comparison of $\mu A1B1$ and $\mu A2B1$ yielded a result of 23.5000*, [Sig. 0.000 < 0.05; CI 95% = 212.156 - 257.844]. A comparison of the effect of $\mu A1B2$ and $\mu A2B2$ is -3.9000*, [Sig. 0.000 < 0.05; CI 95% = -61.844 - -16.156], reinforced by homogeneous results from different sub-sets.

Conclusions. The conclusion of this study is that PBL can be pushed further in the sense that learners enter into real problems, become part of the problem situation, and problems or constraints can be improved in terms of constellation. The findings suggest that there is an interaction between PBL and motivation, the existence of a problem in the form of a task generates motivation to solve it, and the problem is successfully solved when the learner has motivation. Learning with a constraint-led approach must be appropriate to the learner's characteristics, any attempt to increase the task must be given and reviewed very wisely.

Keywords: project-based learning, constraint-led approach, motivation, volleyball.

Introduction

Physical education (PE) in schools and PE/sport pedagogy in universities are required to synergize with the times and the dynamics of science. One of the synergy efforts in question is the transition from the paradigm of teacher-centered learning (TCL) to student-centered learning (SCL) (Rusli et al., 2024; Awaluddin et al., 2023). This transition became the spirit of the formulation of the Merdeka Curriculum (KM) in Indonesia. KM is realized when SCL

and experiential learning are implemented (Azmi & Iswanto, 2022). KM aims to foster 21st-century skills through SCL-based learning (Arrasyid, 2023). SCL-based learning in KM; should be project and problem-based, technology integration, positive environment, and instill resilience in students (Noptario et al., 2024). However, field facts show that KM and SCL in PE in schools and PE/sport pedagogy in universities are still problematic and not running optimally.

The most common problem is the slow transition of teaching and learning habits from TCL to SCL, this problem is found in primary education (Fahrozi et al., 2024), secondary education (Lismana et al., 2022; Is et al., 2024; Fadlan & Anshor, 2022; Wasak & Rohi, 2024), higher education (Sudrajat et al., 2023; Utami et al., 2022; Rochmat et al.,

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2022; Syafruddin & Sutriawan, 2024), and higher education (Rusli et al., 2024; Atmaja et al., 2022). The slow transition is predicted because learners lack motivation and confidence (Safitri et al., 2024; Ezeddine et al., 2023), low critical thinking skills and lack of interactive and collaborative learners (Rahmadi et al., 2023; Dupri et al., 2020). The solution to solve the existing problems is problem-based learning (PBL). PBL is 'problem-based learning' and has better effectiveness than direct learning (Wallace et al., 2020; Pakaya et al., 2023). PBL allows learners to gain experience in identifying the limitations of their knowledge (Saqr et al., 2023). PBL encourages learning motivation, reasoning, and collaboration (Ramdani et al., 2022). PBL characteristics; learners are the core of the learning process, placed in small groups, instructors act as facilitators, and learners are presented with authentic problems at the beginning of learning (Boye & Agyei, 2023).

PBL can be further maximized through the concept of constraint-led approach (C-la). C-la is a learning concept that prioritizes giving tasks in the form of constraint/challenge manipulation, even the constraints/challenges must be increased/difficulties in each phase, with the increasingly difficult constraints/challenges making learners increasingly try to produce specific solutions, play an active role, interact, collaborate, and be motivated (Renshaw et al., 2010; Renshaw & Chow, 2019). There are three types of constraint/challenge manipulation in C-la; organism manipulation (height and weight, fatigue level, and motivation), environment (weather, temperature, light, and social encouragement), and task (rules, equipment, restrictions, opponents, and peers) (Davies et al., 2023). The elaboration of PBL and C-la is new compared to previous research. Using PBL to improve students' critical thinking skills and cooperation in practical courses (Dupri et al., 2020), student's interest and learning effectiveness in exercise physiology courses (X. Liu et al., 2023). Using PBL to improve PE motivation and learning outcomes (Arisetiyana et al., 2020), students' badminton playing skills (Prabandaru et al., 2020), volleyball activeness and learning outcomes (Prasetyo et al., 2022), basketball playing skills (Fadlan & Anshor, 2022; Rahmadi et al., 2023), critical thinking skills (Is et al., 2024), knowledge, attitude, and psychomotor aspects (Wasak & Rohi, 2024). Comparing PBL and Teams Games Tournament on soccer learning outcomes (Panuntun, 2020), PBL and Flipped classroom on pencak silat learning outcomes (Lubis et al., 2022), PBL and conventional PE on increasing motivation and learning outcomes (Ezeddine et al., 2023), cognitive, affective, and psychomotor improvements (Endrawan & Aliriad, 2023).

This study proposes the existence of motivation from the perspective of Self-determination theory (S-dt) as a moderate variable to add novelty value. As well as research comparing Project-Based Learning-based PE, and self-confidence on athletic learning outcomes (Safitri et al., 2024). We propose this because motivation through the S-dt perspective is proven to influence the motion learning process (van Aart et al., 2017). Humans become more motivated when given full authority to determine their own destiny, as they feel they have greater control (Leo et al., 2022). Motivation through the S-dt perspective occurs due to three aspects; (1) Autonomy (being given the authority to determine behavior and goals), (2) Competence (feeling the ability to complete tasks), and (3) Connection/relationship

(completing tasks because they feel related to others) (de Bruijn et al., 2022). For this reason, we propose one of the courses in the PE program in higher education, namely learning volleyball through the PBL model. The hypotheses proposed; (1) There is a difference in influence between the PBL-CBA Model (Elaboration between PBL and constraint-led approach) and the PBL Model (conventional PBL). (2) There is an interaction between PBL model (1 and 2) and motivation (from the Self-determination theory point of view). (3) There is a difference in effect between students who have high and low motivation after undergoing the PBL model (1 and 2).

Materials and Methods

Study Design

The research employed an experimental method with a 2×2 factorial design where treatment was needed. This study was approved by the Ethics Committee of the State University of Makassar.

Participants

The population came from students who were studying volleyball in the PE study program at Megarezky University located in Makassar City, Indonesia, totalling 101 students. Then the sample was drawn using random sampling through a lottery, all selected samples signed an agreement to participate in the study. The selected sample underwent A Test of Self-Determination Theory in the Exercise Domain (Edmunds et al., 2006), then used the Verducci Formula (27 % upper and lower limits) to distribute the sample into 4 groups, resulting in 10 samples/group. Distribution results:

Table 1. Factorial Design

Motivation (B)	PBL Learning Model (A)				Total n
	PBL-CBA Model (A1)	n	PBL Model (A2)	n	
High (B1)	A1B1	10	A2B1	10	20
Low (B2)	A1B2	10	A2B2	10	20

Dependent Variable (C); Volleyball playing skills

Procedures

After the PBL group is formed systematically, then all groups involved are directed to undergo the PBL model. The following is the PBL syntax used in this study. In the first stage according to the PBL Model syntax; (1) Group A1B1 and A1B2 obtained problem orientation by directly experiencing the task/problem given, learners were directly present in the middle of the game, carrying out all and every rule of the game, even the task/problem was increased in each phase; group mates vs group mates, group members vs learners outside the group, and group members vs pro-campus athletes. (2) Groups A2B1 and A2B2 received conventional problem orientation; through literature, discussions, and videos of volleyball playing skills problems. After undergoing treatment, the volleyball lower passing ability test was carried out, the test used in two dimensions,

namely assessing the process and results. To assess the process using test instruments according to (Durrwachter, 1986) and to assess the results using test instruments according to (Widiastuti, 2011).

Statistical Analysis

The prerequisite tests were the normality test using the Kolmogorov Smirnov test ($p > 0.005$) and the homogeneity test using Levene statistics ($p > 0.005$). Furthermore, data analysis uses two-way ANOVA at the significance level $\alpha = 0.05$. If the test results show an interaction then continue with the Tukey test.

Result

Descriptive

Based on table 2, the mean and std. deviation values of A1 [106.60 ± 14.199], A2 [100.45 ± 14.097], A1B1 [120.30 ± 18.885], A1B2 [92.90 ± 22.335], A2B1 [104.10 ± 20.248], A2B2 [96.80 ± 13.165] are known. Minimum and maximum values A1 [90 ± 124], A2 [95 ± 107], A1B1 [117 ± 124], A1B2 [90 ± 96], A2B1 [101 ± 107], A2B2 [95 ± 99].

Table 2. Bottom Serve Results

Group	n	Min $\pm$ Max	Mean $\pm$ SD
A1	20	90 $\pm$ 124	106.60 $\pm$ 14.199
A2	20	95 $\pm$ 107	100.45 $\pm$ 14.097
A1B1	10	117 $\pm$ 124	120.30 $\pm$ 18.885
A1B2	10	90 $\pm$ 96	92.90 $\pm$ 22.335
A2B1	10	101 $\pm$ 107	104.10 $\pm$ 20.248
A2B2	10	95 $\pm$ 99	96.80 $\pm$ 13.165

Prerequisite Test

Based on table 3, A1B1 shows that, with $n = 10$ has a significance of more than 0.200 ($0.200 \geq 0.05$) meaning A1B1 is normally distributed. A1B2 shows that, with $n = 10$ has a significance of more than 0.200 ($0.200 \geq 0.05$) meaning A1B2 is normally distributed. A2B1 shows that, with $n = 10$ has a significance of more than 0.200 ($0.200 \geq 0.05$) meaning A2B1 is normally distributed. A2B2 shows that, with $n = 10$ has a significance of over 0.200 ($0.200 \geq 0.05$) meaning A2B2 is normally distributed.

Table 3. Data normality test results

Group	Kolmogorov-Smirnov		
	Statistics	df	Significance
A1B1	0.11319	10	0.200*
A1B2	0.14097	10	0.200*
A2B1	0.09861	10	0.200*
A2B2	0.11111	10	0.200*

Based on table 4, the results of the Levene-test calculation between A1 and A2, obtained a significant price of $0.216 > 0.05$, thus the two population cells variance (A1 and A2) are Homogeneous.

Table 4. Homogeneity Test Results

Group	Levene Statistics	df1	df2	Sig
A1 and A2	1.560	3	36	0.216

After being declared normal and homogeneous, the variance analysis requirements have been met. Furthermore, hypothesis testing uses two-way analysis of variance (ANOVA). If there is interaction, the analysis used is the Tukey Test.

Table 5. Results of Differences in the Effect of PBL-CBA Model and PBL Model

Source	df	Type III Sum of Squares	Mean Square	F	Sig.
PBL (A)	1	378.225	378.225	105.144	0.000
Motivation (B)	1	3010.225	3010.225	836.819	0.000
A*B interaction	1	1010.025	1010.025	280.779	0.000
Error	36	129.500	3.597		0.000
Total	40	433225.000			

Hypothesis 1

Based on table 5, the price of F (calculate) the difference between the PBL-CBA model (A1) and the PBL model (A2) obtained $F = 105.144$ ($p < 0.05$). Thus there is a significant difference between the PBL-CBA model and the PBL model to improve the results of volleyball lower passing skills. Where PBL-CBA is better than PBL it can be seen from $\mu A1 = 106.6 > \mu A2 = 100.4$.

Hypothesis 2

Based on table 5, the price of F count interaction between PBL model (A) * motivation (B) is obtained = 280.779 with probability level sig = 0.000. Thus it can be concluded that there is a significant interaction between the PBL model (1 and 2) with motivation in the skill of passing under volleyball ($p < 0.05$).

In accordance with the results listed in table 4, further analysis is carried out with the Tukey test. A summary of the results of the Tukey test calculation can be seen in the following table:

Table 6. Multiple Comparisons Tukey HSD

(I) PBL-CBA	(J) PBL	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A1B1	A2B1	23.5000*	.84820	0.000	212.156	257.844
A1B2	A2B2	-3.9000*	.84820	0.000	-61.844	-16.156

Hypothesis 3

Based on table 6, the comparison of the average number of effects of A1B1 and A2B1 is 23.5000 *, the comparison of the average effect of the lower bound is 212.156 and the Upper Bound is 257.844 at the 95 % confidence level, and the Sig value is known. $0.000 < 0.05$. Thus there is a

difference in influence between A1B1 and A2B1, where A1B1 is better than A2B1. Furthermore, the comparison of the average number of influences of A1B2 and A2B2 is -3.9000^* , the comparison of the average influence of the lower bound is -61.844 and the Upper Bound is -16.156 at the 95% confidence level, and the Sig value is known. $0.000 < 0.05$. Thus there is a difference in influence between A1B2 and A2B2, where A2B2 is better than A1B2. These results are also reinforced by the Homogeneous Subsets results (see table 7) that the four PBL groups are in different sub-sets.

Table 7. Homogeneous Subsets

PBL	n	Subset			
		1	2	3	4
A1B2	10	92.90			
A2B2	10		96.80		
A2B1	10			104.10	
A1B1	10				120.30
Sig.		1.000	1.000	1.000	1.000

Discussion

There is a difference in effect between PBL-CBA and PBL, where PBL-CBA is better than PBL. Our findings are in line with other findings that learning with constraint-led approach can encourage people to acquire new skills, adapt, participate in physical activities, and at the same time create a dynamic and explorative learning environment, and foster motivation and creativity (C. Liu, 2023). The existence of improved constraints that are simulated in the learning process helps one to gain new insights in the decision-making process (Sánchez-García, 2023). Manipulating the training environment (constraint-led approach) in volleyball serve training increases students' exploratory power to learn motor skills (Moy, Renshaw, & Gorman, 2024). Perceived constraints support positively predicted effort and engagement in PE (Pan & Hsu, 2024). It is important to modify activities, rules, and equipment, all to increase learning opportunities, foster the perception of developmentally appropriate motor skills, and encourage moderate to vigorous physical activity (Moon & Lee, 2025). Another study that applied constraint-led approach to early childhood by comparing children's success using conventional bicycles, one group of children practicing with assistive wheel bicycles and another group using balance cycles, the trial results showed that children using balance cycles had 100% success compared to assistive wheel bicycles which were only 75 %, this finding was predicted because the balance cycle made children make extra efforts and independence when balancing the bicycle, controlling the speed and braking the bicycle (Mercé et al., 2023). Our results suggest that PBL can be pushed further in the future, so that learners are not only given problems through lecturers' explanations either through stories, assignments, visual information or scripts. It can be pushed further, meaning that the learners enter into the problem in a real way, become part of the problem situation, and even the problem or obstacle is increasing in its constancy over time.

There is an interaction between PBL and motivation, in essence PBL contains the concept of non-pedagogic learning where learners are given the freedom to learn

according to the problem at hand according to their ability to understand and solve the problem. As for motivation (from the point of view of Self-determination theory), it is born from autonomy or authority to determine their behavior and goals, competence to complete the task at hand, and connection/relationship to complete the task because they feel related to others. This means that PBL is able to give way directly or indirectly to learners who have motivation based on the Self-determination theory point of view. Some studies are in line and reinforce the existence of our research results; the learners responded that their motivation increased during the briefing process by the lecturer and the assigned problem solving process (Nor Farida et al., 2012). PBL has an effect on increasing student learning motivation (Safitri et al., 2023; Arisetiyana et al., 2020). There is a difference in increasing student motivation between the two proposed learning methods (PBL and conventional) (Kho et al., 2024). Elaboration between PBL and Discovery Learning effectively increases student motivation and learning outcomes (Panggabean et al., 2023). PBL successfully increases student motivation and learning outcomes, students' badminton playing skills (Prabandaru et al., 2020), PBL-based PE is more effective than conventional PE in junior high school students on increasing motivation and learning outcomes (Ezeddine et al., 2023). It can be seen that there is an intense interaction between the two (PBL and motivation), the existence of problems in the form of tasks raises the motivation of a learner to solve it and problems in the form of tasks can be successfully resolved when the learner has motivation.

There is a difference in the effect between PBL-CBA and PBL, for low and high motivated students, where low motivated students are more suitable for PBL than PBL-CBA and high motivated students are more suitable for PBL-CBA than PBL-CBA. It can be understood that PBL-CBA which contains the concept of constraint-led approach can only be digested by learners when they have high motivation, while PBL tends to be suitable for learners who have low motivation. Many unique things can be assumed from this result, such as learners' independence that must be questioned in solving problems after authority is given (Leo et al., 2022), not to mention the lack of confidence in their competence, as well as the absence of strong group connectivity (de Bruijn et al., 2022), when undergoing the PBL-CBA process. Another important finding that requires further explanation is that low-motivated learners performed better in PBL than PBL-CBA. This phenomenon is possible due to the heavy burden of problems assigned to a person's exercise performance can be disrupted and lead to mental fatigue, for that decrease in task load can be reviewed so as to reduce the demands of cognition and physical performance (Daub et al., 2023; Bahrami, Moradi, & Etaati, 2020). The severity of task load can reduce cognitive performance such as the take-the-first (TTF) heuristic and/or decision-making ability (Cao et al., 2022). Our findings confirm that learning with a constraint- led approach must be appropriate to the characteristics of the learners, any attempt to increase the task must be given and reviewed very wisely.

Conclusion

There is a difference in the effect between PBL-CBA and PBL, where PBL-CBA is better than PBL, thus PBL

can be pushed further in the sense that learners enter into the problem in real terms, become part of the problem situation, and even the problem or obstacle is increasingly enhanced over time. There is an interaction between PBL and motivation (from the viewpoint of Self-determination theory), meaning that the existence of a problem in the form of a task raises the motivation of a learner to solve it and the problem in the form of a task can be successfully solved when the learner has motivation. There is a difference in the effect between PBL-CBA and PBL, on students who have low and high motivation, where students who have low motivation are more suitable for PBL than PBL-CBA and students who have high motivation are more suitable for PBL-CBA than PBL-CBA, thus learning with a constraint-led approach must be in accordance with the characteristics of the learner, the effort to add tasks must be given and reviewed very wisely. PE and sport pedagogic/education learning in the future can be maximized with PBL or other learning models that are student centered learning and non-pedagogic learning through joint elaboration of the concept of constraint-led approach, and pay attention to motivation from the perspective of Self-determination theory. Of course, this conclusion requires further research in the future.

Conflict of interest

The authors have no conflicts of interest to declare.

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Комплексний підхід до підвищення спортивної майстерності у волейболі: Роль проблемно-орієнтованого навчання, обмежено-керованого підходу та мотивації

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 8 с., 6 табл., 48 джерел.

Мета дослідження. Це дослідження мало на меті визначити, чи існують відмінності у впливі між розв'язанням задач на основі обмежень (Constraint-Based Problem-Solving, CBA-PBL) та проблемно-орієнтованим навчанням (Problem-Based Learning, PBL), чи є взаємозв'язок між моделлю PBL-CBA та мотивацією, а також чи спостерігається різниця щодо впливу між студентами з високим та низьким рівнем мотивації після застосування моделей PBL-CBA та PBL.

Матеріали та методи. У дослідженні використовувався експериментальний метод із застосуванням факторіального дизайну 2 × 2, де необхідним було проведення випробування, в якому брали участь 40 студентів.

Результати. За результатами дослідження отримано значення F-розрахунку PBL-CBA (A1) та PBL (A2) = 105,144 (p < 0,05), що свідчить про достовірну різницю показників (μA1 = 106,6 > μA2 = 100,4). Взаємодія F-розрахунку PBL (A)*мотивація (B) = 280,779 (p < 0,05), що вказує на суттєвий взаємозв'язок. Порівняльний аналіз μA1B1 і μA2B1 показав результат 23,5000*, [Sig. 0,000 < 0,05; CI 95% = 212,156 - 257,844]. Порівняння ефекту μA1B2 і μA2B2 становить -3,9000*, [Sig. 0,000 < 0,05; CI 95% = -61,844 - -16,156], що підтверджується однорідними результатами з різних підмножин.

Висновки. У цьому дослідженні зроблено висновок про можливість подальшого розвитку методу PBL в тому розумінні, що учні стикаються з реальними труднощами, стають частиною проблемної ситуації, а самі складнощі або обмеження можна поліпшити з точки зору констеляції. Результати дослідження вказують на наявність взаємодії між методом

PBL і мотивацією, існування проблеми у вигляді завдання породжує мотивацію до її розв'язання, при цьому проблема успішно вирішується в умовах наявності в учня мотивації. Навчання із застосуванням обмежено-керованого підходу має враховувати індивідуальні особливості учня, а будь-яка спроба підвищити складність завдання має надаватися та розглядатися з максимальною раціональністю.

Ключові слова: навчання з використанням проєктів, обмежено-керований підхід, мотивація, волейбол.

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Original Scientific Article

Determining the Influence of Coaches, Parents, and Stakeholders on the Development of Youth Football: A Comprehensive Analysis

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Abstract

Background. The development of youth football is significantly influenced by collaborative coaches, parents, and stakeholders, who play a pivotal role in shaping athletes' experiences and long-term engagement. Coaches provide structured training, emotional support, and discipline, while parents offer guidance without undue pressure. Stakeholders, including authorities and governing bodies, ensure governance, resources, and policy frameworks. Their collaboration fosters skill development, psychological growth, and sustained athletic success.

Objectives. This study aimed to examine the impact of coaches, parents, and stakeholders on the development of youth football, highlighting their contributions and the importance of collaborative frameworks.

Materials and methods. A quantitative research design was employed, collecting data from young male footballers in Gimbi Administrative Town, Ethiopia. Standardized questionnaires were used to assess the perspectives of coaches, parents, and stakeholders, with reliability coefficients of ($\alpha = 0.796, 0.817, \text{ and } 0.752$), respectively. Statistical analysis was conducted using SPSS 26, applying descriptive statistics, Pearson correlation, one-way ANOVA, and multiple regression analysis at a 0.05 significance level.

Results. The findings revealed that coaching had the most significant impact on youth football development ($\beta = 0.799, p < 0.001$), followed by stakeholder involvement ($\beta = 0.514, p = 0.049$), while parental engagement played a supporting role ($\beta = 0.266, p = 0.032$). A strong positive correlation was found between coaching and youth football success ($r = 0.843, p < 0.01$). Parental involvement showed a moderate to strong positive correlation ($r = 0.695, p < 0.05$), while stakeholder support exhibited a moderate correlation ($r = 0.677, p < 0.01$). The ANOVA results confirmed significant differences in stakeholder, parental, and coaches' perspectives on football development ($F = 47.724, p < 0.001$).

Conclusions. The study underscores the vital roles of coaches, stakeholders, and parents in youth football development, advocating for better coaching education, stakeholder investment, and balanced parental involvement. Strong collaboration is key to a sustainable and holistic development model.

Keywords: youth football development, coach, parental involvement, stakeholders.

Introduction

The development and improvement of youth football are notably dictated by the unified contributions and effects

of coaches, parents, and local authorities, with each of these groups holding a vital position in crafting the experiences and eventual outcomes that young athletes undergo during their sporting pursuits. A thorough understanding of these complex interactions elucidates how these pivotal stakeholders facilitate the creation of a supportive atmosphere that not only fosters development but also amplifies the satisfaction experienced within the domain of sports (Mola & Shaw, 2024a).

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Coaches, parents, and stakeholders play pivotal roles in shaping the future of youth football by fostering positive developmental environments and enhancing athlete experiences (Mola & Shaw, 2024a). The collaborative efforts of these key figures significantly influence the growth and success of young footballers, ensuring a balance between skill development, personal growth, and long-term engagement in sports (Mola & Shaw, 2024b). By working together, these individuals can create a comprehensive support system that nurtures young athletes, both on and off the field.

Coaches serve as the foundation of youth football development by implementing age-appropriate training programs and fostering cognitive and psychological skills. They play a crucial role in promoting professional conduct and moral role modeling, which is essential for shaping young athletes' character (Harwood & Knight, 2014). Also, the role of coaches in fostering emotional competence and psychological well-being among young athletes is critical, as evidenced by various studies. Martínez-Pampliega et al. (2023) highlight that coaches' emotional competencies significantly influence the training climate, which in turn affects athletes' emotional skills and reduces symptoms of emotional distress. By establishing a motivating environment, coaches enhance moral attitudes, emotional well-being, and overall psychological health. A task-oriented climate that prioritizes learning and improvement over mere victory has been shown to correlate with improved well-being, resilience, and a sense of security among young athletes (Shanmugaratnam et al., 2024). Additionally, cooperative learning strategies, where mistakes are seen as learning opportunities rather than failures, help athletes develop stronger connections with coaches and teammates, leading to improved social and emotional well-being (Kipp & Bolter, 2023). Furthermore, coaches serve as mentors; guiding players through challenges and helping them develop critical thinking skills that extend beyond the football field. Their influence extends to instilling discipline, teamwork, and a growth mindset that can benefit young athletes in various aspects of their lives.

Parents play an equally vital role by providing emotional and logistical support for their children's participation in football. Their involvement can significantly influence young athletes' motivation and enjoyment, with research highlighting the importance of balancing encouragement with realistic expectations (Bognár et al., 2024; Scholle, 2023). While parents often prioritize both academic and athletic achievements, excessive pressure can hinder a child's enjoyment and development. Studies have underscored the necessity for effective coach-parent collaboration to ensure a supportive environment that fosters both competitive success and personal growth (Bettega et al., 2023). Recognizing the fine line between encouragement and undue pressure is crucial in maintaining young players' enthusiasm and mental well-being. In addition, parents contribute to the development of positive habits such as time management, healthy nutrition, and emotional resilience, which are essential for sustaining long-term athletic and personal success.

Stakeholders, including local authorities and governing bodies, contribute to youth football by creating structured pathways and governance models that align with long-term strategic goals. Effective communication and collaboration among these groups are essential to maintaining consistency

in developmental processes and optimizing young athletes' experiences (Sweeney et al., 2022). A unified approach ensures that football development not only nurtures athletic talent but also instills essential life skills such as teamwork, resilience, and discipline. However, research suggests that young footballers primarily develop life skills through implicit experiences rather than structured programs (Cope et al., 2016). Addressing this gap by integrating life-skills education into training regimens can better prepare athletes for challenges beyond sports, equipping them with tools for both personal and professional success. Additionally, governing bodies play a crucial role in ensuring that clubs and academies adhere to best practices in athlete development, providing access to quality coaching, safe facilities, and structured career pathways for young players.

The alignment of perceptions among stakeholders regarding talent identification and development is critical for creating coherent support systems (Pankhurst & Collins, 2013). A shared vision ensures that young athletes receive the necessary guidance, opportunities, and encouragement to thrive. When stakeholders work together effectively, they foster an environment that values both performance and holistic development, encouraging open communication and mutual understanding. This collaborative effort enhances individual performance while promoting a culture of respect and inclusivity, ultimately benefiting young athletes on and off the field. Furthermore, long-term planning and investment in youth programs can enhance talent identification and provide a clear progression route from grassroots to elite levels, ensuring that no promising athlete is overlooked due to systemic gaps (Mola & Shaw, 2024a).

While the contributions of coaches, parents, and stakeholders are undeniably significant, challenges such as differing expectations, pressures, and potential conflicts must also be acknowledged. Open communication, regular feedback, and shared goals are essential in addressing these challenges, ensuring that youth football remains a positive and nurturing experience. By maintaining a harmonious balance among these influences, young athletes can excel both personally and athletically, fostering a sustainable and enriching sporting culture for future generations. Moreover, continuous education and training for all stakeholders, including workshops and mentorship programs, can bridge gaps in understanding and create a more cohesive developmental system. A commitment to ongoing evaluation and improvement will help refine youth football programs, ensuring that they continue to evolve in ways that prioritize both competitive success and holistic athlete development.

Material and Methods

Study Design and Participants

The research was developed and adapted from prior foundational studies. The perspective of coaches was examined through a standardized questionnaire based on the seminal work of Côté & Gilbert (2009), which investigated how coaching methodologies influence athlete development. Their research emphasized the essential role of coaches in guiding the technical, tactical, and psychological growth of young athletes through structured training and mentorship frameworks. Similarly, the viewpoint of parents was explored

using a standardized questionnaire inspired by Fredricks and Eccles (2005). Their work focused on quantifying parental engagement in youth sports, addressing key dimensions such as support, pressure, and communication.

The perspective of stakeholders was analyzed through a standardized questionnaire grounded in the research of Misener & Doherty (2013), who assessed the contributions and challenges faced by stakeholders in community sports development. Sotiriadou et al. (2013) extended this exploration by examining stakeholder roles in shaping sports policy and development, using surveys to gather data on talent identification, resource distribution, and infrastructure enhancement. The study sample consisted of 59 male players from Gimbi, Administrative Town, who were regularly committed and actively participated in training. They represented multiple developmental stages: U16–U17 (competitive youth football, focusing on physical growth and advanced tactical introduction), U18–U19 (final youth stage, preparing for professional or elite-level competition), and U20–U21 (early senior-level football, often involving reserve teams or U21 national squads). A purposive sampling method was utilized to select participants relevant to the research objectives. Quantitative data analysis was performed using SPSS version 26. The study prioritized the rights of participants by ensuring they were consistently informed throughout the research process. Confidentiality and anonymity were strictly upheld, and participants retained the right to withdraw at any stage. The research aimed to explore the role of coaches, parents, and stakeholders in shaping the future of youth football, with a particular focus on gaining football-related insights while adhering to ethical research standards.

Procedure

The study was conducted with 59 participants, incorporating the translation of the questionnaire into Afan Oromo to enhance clarity and accessibility. The refinement process ensured high reliability, yielding Cronbach's alpha values of $\alpha = 0.796$ for coaches, $\alpha = 0.817$ for parents, $\alpha = 0.752$ for stakeholders, and, for youth football development $\alpha = 0.730$. A preliminary investigation was undertaken to evaluate the clarity, appropriateness, and length of the questionnaire. Ambiguous terms were meticulously reviewed and revised to improve accuracy and comprehension.

A purposive sampling method was utilized to strategically select a sample of 59 participants, representing the club population based on their respective roles. Ethical considerations were central to the study, ensuring informed consent, confidentiality, and the overall well-being of participants. The research adhered to principles of transparent communication, cultural sensitivity, and full disclosure of potential conflicts of interest, reinforcing its ethical foundation.

This research procedure aimed to provide valuable insights into the influence of coaches, parents, and stakeholders in shaping the future of Data collected from 59 male youth football players aged U16–U17, U18–U19, and U20–U21 in Gimbi Administrative Town. By maintaining methodological rigor and adhering to ethical standards, the study aimed to generate meaningful and reliable findings that could contribute to the development and enhancement of youth football programs (Taye et al., 2024).

Data Collection Procedure

The data collection process followed a structured approach to ensure accuracy, reliability, and ethical compliance. Participants were first briefed on the study's objectives, their rights, and the voluntary nature of their participation. Informed consent was obtained before administering the questionnaire. The study utilized a structured 60-item questionnaire designed to assess key variables, including the role of coaches, parents, and stakeholders in youth football development. The questionnaire was formatted in a tabular style, incorporating a Likert scale ranging from 1 to 5 to facilitate standardized responses. Data were collected from 59 male youth football players aged U16–U17, U18–U19, and U20–U21 in Gimbi Administrative Town. Researchers distributed the questionnaire during designated team meetings and ensured that participants completed it independently to minimize bias. To maintain consistency and clarity, a researcher was present to provide explanations if needed. After collection, the data was carefully reviewed for completeness before being entered into SPSS version 26 for quantitative analysis. Statistical methods were applied to identify patterns, correlations, and trends relevant to the study objectives. Throughout the process, strict measures were implemented to protect participant confidentiality and ensure compliance with ethical research standards.

Reliability and Validity of Instruments

As an initial evaluation, the reliability and validity of the questionnaire items were assessed using Cronbach's alpha to ensure the instrument's consistency. The Computed Cronbach's alpha (α) value was coaches prospectives $\alpha = 0.796$, parental prospectives $\alpha = 0.817$, and stakeholder prospectives $\alpha = 0.752$, and development of youth football $\alpha = 0.730$ indicating a high level of internal reliability. Additionally, the instrument underwent a thorough validation process, during which subject matter experts and language specialists rigorously reviewed the questions to determine their effectiveness in measuring the intended research variables. To further refine the instrument, a preliminary study was conducted with a small group of athletes who shared similar characteristics with the primary participants. This pilot study followed established research design principles, as outlined by (Mola & Shaw, 2024c). It aimed to evaluate the effectiveness of the data collection methods, ensure participant comprehension of the survey content, and improve the overall accuracy and clarity of the questionnaire. Through these reliability and validity measures, the study ensured the collection of precise and meaningful data aligned with the research objectives.

Table 1. Reliability statistics cronbach's alpha result

Variable	Cronbach' Alpha	No Items
Coaches prospectives	$\alpha = 0.796$	16
Parental prospectives	$\alpha = 0.817$	15
Stakeholder prospectives	$\alpha = 0.752$	24
Development and Success of Youth Football	$\alpha = 0.730$	5
Overall Reliability	$\alpha = 0.793$	60

Statistical Analysis

The study employed SPSS version 26 to analyze athletes' perspectives and characteristics using comprehensive statistical methods. A five-point scale was utilized, with descriptive statistics frequency, percentages, meaning, and standard deviation summarizing participants' views across various dimensions. Also, Pearson correlation coefficients, one-way ANOVA, and multiple regression analysis were conducted. A significant level of 0.05 was applied to ensure statistical robustness, enhancing the reliability and validity of the findings. By integrating these analytical approaches, the study provides a holistic evaluation of the interconnected roles of coaches, parents, and stakeholders in fostering youth sports development.

Results

Table 2. Demographic characteristics

Variable	Category	Frequency	Percent
Sex	Male	59	100
	Total	59	100
Age	under 18	37	62.7
	18-23	22	37.3
	Total	59	100
Youth Competitive Level	under U17 youth football	20	33.9
	U17-18youth football	18	30.5
	U18-19youth football	21	35.6
	Total	59	100.0
Educational of Coaches	Basic coaching certificate	5	8.5
	Advanced coaching certificate	13	22.0
	Degree	34	57.6
	Masters	7	11.9
	Total	59	100.0

The demographic characteristics of the study sample consisted of 59 male participants, making up 100% of the respondents. The age distribution indicates that the majority (62.7%) are under 18 years old, while 37.3% fall within the 18-23 age range, suggesting that the study primarily focuses on younger athletes in the early stages of their football careers. Regarding competitive levels, 33.9% of the participants compete in U17 youth football, 30.5% in U17-U18, and 35.6% in U18-U19, showing a relatively balanced representation across different developmental stages, with a slight concentration in the U18-U19 category, where athletes transition to higher competition levels. In terms of educational background, the majority (57.6%) hold a degree, while 22.0% have an advanced coaching certificate, 8.5% possess a basic coaching certificate, and 11.9% have obtained a master's degree.

Table 3. The correlation between the role of coaches, parents, and stakeholders in the development and success of youth football

Coefficient of correlation (r)		
Variable	r	Sig. (2-tailed)
Coaches' perspective	.843**	.000
Parental perspective	.695*	.043
Stakeholder Prospective	.677**	.000

A Pearson product-moment correlation analysis was conducted on a sample of 59 participants to examine the

relationships between Coaches' Perspective, Parental Perspective, Stakeholder Perspective, and the Development and Success of Youth Football.

The results revealed a strong positive correlation between Coaches' Perspective and Development and Success of Youth Football ($r = 0.843$, $p < 0.01$), indicating that as the role of coaches improves, youth football development significantly increases. Similarly, Parental Perspective showed a moderate positive correlation with the Development and Success of Youth Football ($r = 0.695$, $p < 0.05$), suggesting that parental involvement contributes positively, though not as strongly as coaching. Likewise, a moderate positive correlation was found between Stakeholder Perspective and Youth Football Development ($r = 0.677$, $p < 0.01$), confirming that stakeholder engagement plays an important role in fostering football success.

Coaches, parents, and stakeholders play pivotal roles in shaping the development and success of youth football by fostering positive environments and relationships that enhance athletes' experiences. Research indicates that effective coaching practices, characterized by strong interpersonal skills and a focus on youth development, significantly contribute to positive outcomes such as increased motivation and reduced anxiety among young athletes. Parents also influence this dynamic by supporting their children's participation and aligning their values with developmental goals, which can enhance the overall youth sports experience. Furthermore, the collaboration between coaches, parents, and governing bodies is essential for coherent talent identification and development strategies, ensuring that all stakeholders share a common understanding of key constructs like athlete development and specialization. Collectively, these elements underscore the importance of intentional practices and communication among all parties involved in youth football.

A multiple regression analysis was conducted to examine the impact of Coaches' Perspective, Parental Perspective, and Stakeholder Perspective on the Development and Success of Youth Football. The results indicate that the overall model is statistically significant ($p < 0.01$), suggesting that these independent variables collectively influence the success of youth football. Among the predictors, Coaches' Perspective emerged as the strongest predictor ($B = 0.551$, $\beta = 0.799$, $t = 10.454$, $p < 0.001$), indicating that increased coaching involvement leads to a substantial improvement in youth football development. For every one-unit increase in coaching involvement, the success of youth football increases by 0.551 units, highlighting the critical role of coaches in fostering growth.

The Parental Perspective also showed a positive effect on youth football development ($B = 0.421$, $\beta = 0.266$, $t = 0.906$, $p = 0.032$), though its influence was weaker compared to coaching and stakeholders. The p-value (0.032) suggests that while parental involvement contributes to football success, its impact is less substantial. In contrast, the Stakeholder Perspective demonstrated a strong positive effect ($B = 0.430$, $\beta = 0.514$, $t = 1.463$, $p = 0.049$), making it the second most influential factor after coaching. A one-unit increase in stakeholder engagement results in a 0.430 unit increase in football success, confirming that support from stakeholders such as local authorities, sponsors, and football organizations plays a crucial role.

Table 4. Coefficient table

Coefficients ^a							
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Upper Bound	Lower Bound
(Constant)	-6.903	2.127		3.246	.002	11.165	2.641
1 Coaches' perspective	.551	.034	.799	10.454	.000	.284	.418
Parental Prospective	.421	.023	.266	.906	.032	.026	.068
Stakeholder Prospective	.430	.021	.514	1.463	.049	.011	.072

a. Dependent Variable: Development and Success of Youth Football

Table 5. Model estimation

Model Summary									
Model	R	R ²	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.850 ^a	.722	.707	1.64336	.722	47.724	3	55	.000

a. Predictors: (Constant), Stakeholder perspective, parental perspective, Coaches Perspective

Table 6. The impact of coaches, parents, and stakeholders on the development and success of youth football

ANOVA ^a						
Model	Sum of Squares	df	Mean Square	F	Sig.	
1 Regression	386.652	3	128.884	47.724	.000 ^b	
Residual	148.534	55	2.701			
Total	535.186	58				

a. Dependent Variable: Development and Success of Youth Football

b. Predictors: (Constant), Stakeholder Prospective, parental perspective, Coaches Perspective

Table 7. Coaches, parents vs stakeholders in youth football development

ANOVA						
Variable	Sum of Squares	df	Mean Square	F	Sig.	
Coaches prospective	Between Groups	1257.973	29	43.378	.830	.000
	Within Groups	1515.417	29	52.256		
	Total	2773.390	58			
Parental perspective	Between Groups	3367.175	29	116.109	1.801	.047
	Within Groups	1869.333	29	64.460		
	Total	5236.508	58			

The Model Summary indicates that the predictors collectively explain 72.2% of the variance in youth football development ($R^2 = 0.722$), with an adjusted R^2 of 0.707, confirming a strong model fit. The standard error of the estimate (1.64336) suggests a reasonable level of prediction accuracy.

The ANOVA results further confirm the significance of the model ($F(3,55) = 47.724$, $p < 0.001$), indicating that the independent variables significantly contribute to explaining the dependent variable. The high F-statistics (47.724) and the very low p-value ($p < 0.001$) suggest that the combination of coaches, parents, and stakeholders' perspectives plays a crucial role in shaping youth football success. These results

highlight that coaches, stakeholders, and parents collectively influence football development, with coaching having the most substantial impact. The findings emphasize the need for enhancing coaching programs, encouraging stakeholder investment, and strengthening parental engagement to maximize the growth and success of youth football.

An ANOVA analysis was conducted to compare the differences in responses among Coaches, Parents, and Stakeholders regarding their perspectives on the Development and Success of Youth Football. The results indicate significant differences in how these groups perceive their roles in youth football development. From the Coaches' Perspective, the analysis shows that the between-group

sum of squares (1257.973) and the within-group sum of squares (1515.417) resulted in an F-value of 0.830, which is statistically significant ($p = 0.000$). This suggests that there are substantial differences among the groups in how they view the role of coaches in football development. For the Parental Perspective, the between-group sum of squares (3367.175) and the within-group sum of squares (1869.333) resulted in an F-value of 1.801, with a p-value of 0.047. Since $p < 0.05$, this indicates that parental perspectives on football development differ significantly between groups.

Discussion

The demographic characteristics of the study sample consisted of 59 male participants, making up 100% of the respondents. The age distribution indicates that the majority (62.7%) are under 18 years old, while 37.3% fall within the 18–23 age range, suggesting that the study primarily focuses on younger athletes in the early stages of their football careers. Regarding competitive levels, 33.9% of the participants compete in U17 youth football, 30.5% in U17–U18, and 35.6% in U18–U19, showing a relatively balanced representation across different developmental stages, with a slight concentration in the U18–U19 category, where athletes transition to higher competition levels. Regarding the educational background of coaches, youth footballers reported that the majority (57.6%) hold a degree, while 22.0% have an advanced coaching certificate, 8.5% possess a basic coaching certificate, and 11.9% have attained a master's degree. This suggests that a significant portion of the participants have a strong academic or coaching foundation, potentially enhancing their understanding of sports science, training methodologies, and nutrition.

A Pearson product-moment correlation analysis was conducted on a sample of 59 participants to examine the relationships between Coaches' Perspective, Parental Perspective, Stakeholder Perspective, and the Development and Success of Youth Football. The results revealed a strong positive correlation between Coaches' Perspective and Development and Success of Youth Football ($r = 0.843$, $p < 0.01$), indicating that as the role of coaches improves, youth football development significantly increases. Similarly, Parental Perspective showed a moderate positive correlation with the Development and Success of Youth Football ($r = 0.695$, $p = 0.043$), suggesting that parental involvement contributes positively, though not as strongly as coaching. Likewise, a moderate positive correlation was found between Stakeholder Perspective and Youth Football Development ($r = 0.677$, $p < 0.01$), confirming that stakeholder engagement plays an important role in fostering football success.

The analysis also revealed strong positive interrelationships between the independent variables. There was a strong correlation between Coaches' Perspective and Parental Perspective ($r = 0.713$, $p = 0.014$), suggesting that greater coaching involvement is associated with increased parental engagement. Additionally, a strong correlation between Coaches' Perspective and Stakeholder Perspective ($r = 0.746$, $p = 0.013$) indicates that enhanced coaching efforts align with greater stakeholder participation. However, the relationship between Parental Perspective and Stakeholder Perspective was moderate but not statistically significant ($r = 0.687$, $p = 0.156$), implying that parental and stakeholder

roles may operate independently rather than in direct collaboration.

Coaches, parents, and stakeholders play pivotal roles in shaping the development and success of youth football by fostering positive environments and relationships that enhance athletes' experiences. Research indicates that effective coaching practices, characterized by strong interpersonal skills and a focus on youth development, significantly contribute to positive outcomes such as increased motivation and reduced anxiety among young athletes (Bengtsson et al., 2023, Dandurand & Heidt, 2022). Parents also influence this dynamic by supporting their children's participation and aligning their values with developmental goals, which can enhance the overall youth sports experience (Scholle, 2023; Pankhurst et al., 2013). Furthermore, the collaboration between coaches, parents, and governing bodies is essential for coherent talent identification and development strategies, ensuring that all stakeholders share a common understanding of key constructs like athlete development and specialization (Pankhurst et al., 2013). Collectively, these elements underscore the importance of intentional practices and communication among all parties involved in youth football (Bloom et al., 2020).

A multiple regression analysis was conducted to examine the impact of Coaches' Perspective, Parental Perspective, and Stakeholder Perspective on the Development and Success of Youth Football. The results indicate that the overall model is statistically significant ($p < 0.01$), suggesting that these independent variables collectively influence the success of youth football. Among the predictors, Coaches' Perspective emerged as the strongest predictor ($B = 0.551$, $\beta = 0.799$, $t = 10.454$, $p < 0.001$), indicating that increased coaching involvement substantially improves youth football development. For every one-unit increase in coaching involvement, the success of youth football increases by 0.551 units, highlighting the critical role of coaches in fostering growth.

The Parental Perspective also positively affected youth football development ($B = 0.421$, $\beta = 0.266$, $t = 0.906$, $p = 0.032$), though its influence was weaker compared to coaching and stakeholders. The p-value (0.032) suggests that while parental involvement contributes to football success, its impact is less substantial. In contrast, the Stakeholder Perspective demonstrated a strong positive effect ($B = 0.430$, $\beta = 0.514$, $t = 1.463$, $p = 0.049$), making it the second most influential factor after coaching. A one-unit increase in stakeholder engagement results in a 0.430 unit increase in football success, confirming that support from stakeholders such as local authorities, sponsors, and football organizations plays a crucial role. This aligns with recent studies that suggest parental involvement can enhance youth sports experiences but may also have limitations. Bonavolontà et al. (2021) found that parental support, such as providing emotional encouragement and facilitating access to resources, positively influences youth athletes' enjoyment and commitment to sports. However, the study also noted that excessive parental pressure or over-involvement can lead to burnout and decreased motivation among young athletes. The moderate influence of parental involvement in this study suggests that while parents play a supportive role, their impact is secondary to that of coaches and stakeholders.

The Stakeholder Perspective emerged as the second most influential factor ($B = 0.430$, $\beta = 0.514$, $p = 0.049$). This finding is supported by recent literature that highlights the importance of external support systems in youth sports. For instance, Brown et al. (2023) emphasized that stakeholders such as local authorities, sponsors, and football organizations provide essential resources, including funding, facilities, and organizational structures, which are critical for the sustainability and growth of youth sports programs. Additionally, a study by Brown et al. (2023) found that stakeholder engagement fosters community involvement and creates a supportive ecosystem for youth development. The significant positive effect of stakeholder engagement in this study underscores the need for collaborative efforts among various entities to ensure the success of youth football.

The findings of this study are well-supported by recent literature, which highlights the critical roles of coaches, parents, and stakeholders in youth football development. Coaches' Perspective stands out as the most influential factor, emphasizing the need for skilled and dedicated coaches. Parental involvement, while beneficial, has a more modest impact, and stakeholder engagement plays a vital role in providing the necessary resources and support. Together, these perspectives create a comprehensive framework for the success of youth football programs. Overall, these findings suggest that coaching has the greatest impact on youth football development, followed by stakeholder involvement, while parental engagement plays a smaller yet significant role. Based on these results, it is recommended that investments in coaching programs be prioritized to enhance player development and overall success. Additionally, fostering greater stakeholder participation can further improve outcomes, while strategies to enhance parental engagement should be considered to maximize their contribution to youth football success.

The Model Summary indicates that the predictors collectively explain 72.2% of the variance in youth football development ($R^2 = 0.722$), with an adjusted R^2 of 0.707, confirming a strong model fit. The standard error of the estimate (1.64336) suggests a reasonable level of prediction accuracy.

The ANOVA results further confirm the significance of the model ($F(3,55) = 47.724$, $p < 0.001$), indicating that the independent variables significantly contribute to explaining the dependent variable. This suggests that the combination of coaches, parents, and stakeholders' perspectives plays a crucial role in shaping youth football success. These results highlight that coaches, stakeholders, and parents collectively influence football development, with coaching having the most substantial impact. The findings emphasize the need for enhancing coaching programs, encouraging stakeholder investment, and strengthening parental engagement to maximize the growth and success of youth football. These findings are consistent with existing literature emphasizing the multifaceted support system in youth sports.

Parent education programs in youth sports are essential for enhancing parental support and involvement, which significantly influences children's sporting experiences. These programs equip parents with the knowledge and skills needed to foster a positive environment, encouraging their children to thrive both on and off the field. Effective communication within these programs also helps to align expectations and promote a shared vision for the child's

development, ultimately contributing to a more enriching sporting experience. This collaborative approach not only enhances the child's performance but also strengthens the bond between parents, coaches, and athletes, creating a supportive community that prioritizes holistic development. These programs facilitate healthy parental engagement by providing strategies that alleviate stressors and promote positive interactions between parents and coaches (Maciel et al., 2024; Burke et al., 2021). This proactive involvement ensures that parents feel empowered and informed, allowing them to play an integral role in their child's athletic journey while fostering a culture of respect and teamwork. By prioritizing open communication and mutual understanding, these initiatives not only benefit the athletes but also cultivate an environment where everyone involved can thrive both on and off the field. Such an environment enhances the overall experience of youth sports, encouraging athletes to develop not only their physical skills but also essential life skills such as leadership, resilience, and collaboration.

Research indicates that effective parental involvement can lead to improved athlete development, fostering a supportive environment that prioritizes youth well-being and safety (Scholle, 2023; Tafuri & Priore, 2020). This collaborative approach ensures that young athletes feel valued and understood, ultimately motivating them to reach their full potential while enjoying the benefits of physical activity and social interaction. Creating a culture of open communication between coaches, parents, and athletes is crucial in reinforcing these values, as it helps to establish trust and mutual respect among all parties involved. Furthermore, the dynamics of parent-coach relationships are crucial, as they can either enhance or hinder a child's sporting journey, emphasizing the need for collaborative efforts to optimize these interactions (Gao et al., 2024; Dorsch et al., 2020). Overall, structured educational initiatives can empower parents, ensuring they contribute positively to their children's sports experiences while aligning with best practices in youth development (Bruner et al., 2021).

Strengths and Future Implications

Strengths

This study provides a well-rounded analysis by integrating coaches', parents', and stakeholders' perspectives, demonstrating their collective impact on youth football development. With strong statistical significance ($R^2 = 0.722$), the findings highlight the predictive power of these factors in shaping football success. Positive correlations confirm that coaching, parental support, and stakeholder engagement are key drivers of athlete development. The study combines both qualitative and quantitative elements, offering valuable insights for improving youth sports programs. The results provide a clear direction for enhancing youth football, emphasizing better coaching programs, increased stakeholder involvement, and effective parental education initiatives.

Future Implications

Future research should focus on developing educational programs to enhance parents' role in youth football, ensuring

their support aligns with developmental goals. Since coaching has the strongest influence, investing in advanced training programs could further optimize youth football outcomes. Stakeholder involvement is also crucial, and future studies should explore ways to improve collaboration between sponsors, local authorities, and sports organizations. Longitudinal studies could assess the long-term impact of these relationships; while expanding the sample to include female athletes and diverse cultural backgrounds could offer broader insights.

Limitations

The study's small sample of 59 male participants limits its generalizability, especially for female athletes and other underrepresented groups. Its cross-sectional design captures only a moment in time, making it difficult to assess long-term effects. The study focuses on coaches, parents, and stakeholders but overlooks other influential factors like teammates, community support, and athletes' perspectives. Additionally, reliance on self-reported data may introduce bias, affecting accuracy. Strong correlations suggest possible overlap in the influence of coaches, parents, and stakeholders, requiring further research to clarify their contributions.

Conclusions

The study highlights the crucial roles of coaches, parents, and stakeholders in youth football success, with coaching having the most significant impact. While parental involvement plays a supportive role, stakeholder engagement emerges as the second most influential factor. Together, these perspectives explain a substantial portion of youth football development, emphasizing the need for collaboration. Prioritizing coaching programs, increasing stakeholder participation, and developing educational initiatives for parents can enhance youth sports programs. Further research should explore long-term effects and diverse.

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Conflicts of Interest

The authors declare no conflicts of interest.

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Визначення впливу тренерів, батьків та зацікавлених сторін на розвиток дитячо-юнацького футболу: Комплексний аналіз

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

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Історія питання. На розвиток дитячо-юнацького футболу значною мірою впливає співпраця тренерів, батьків та зацікавлених сторін, які відіграють ключову роль у формуванні досвіду спортсменів та їхньої довготривалої залученості.

Тренери забезпечують структуровану підготовку, емоційну підтримку та дотримання дисципліни, тоді як батьки надають необхідні поради, не чинячи надмірного тиску. Зацікавлені особи, включно з представниками влади та керівними органами, забезпечують належне управління, ресурси та директивні механізми. Їхня співпраця сприяє розвитку навичок, психологічному зростанню та сталому успіху в спорті.

Мета дослідження. Це дослідження мало на меті вивчити вплив тренерів, батьків та зацікавлених сторін на розвиток дитячо-юнацького футболу, підкреслюючи їхній внесок та важливість механізмів співпраці.

Матеріали та методи. У роботі застосовано кількісний метод дослідження, що полягав у зборі даних, отриманих від юнаків-футболістів в адміністративному місті Гімбі (Ефіопія). Для визначення поглядів тренерів, батьків та зацікавлених сторін використовувались стандартизовані опитувальники з коефіцієнтами надійності ($\alpha = 0,796, 0,817$ та $0,752$), відповідно. Статистичний аналіз проведено за допомогою програмного забезпечення SPSS 26 із застосуванням описової статистики, кореляції Пірсона, однофакторного дисперсійного аналізу та множинного регресійного аналізу на рівні значущості 0,05.

Результати. За результатами дослідження встановлено, що найбільший вплив на розвиток дитячо-юнацького футболу має тренерська діяльність ($\beta = 0,799, p < 0,001$), наступним фактором є залученість зацікавлених сторін ($\beta = 0,514, p = 0,049$), тоді як участь батьків у цьому процесі відіграє допоміжну роль ($\beta = 0,266, p = 0,032$). Виявлено сильну позитивну кореляцію між тренерською діяльністю та успіхами у дитячо-юнацькому футболі ($r = 0,843, p < 0,01$). Залученість батьків показала помірну та сильну позитивну кореляцію ($r = 0,695, p < 0,05$), натомість підтримка зацікавлених сторін продемонструвала помірну кореляцію ($r = 0,677, p < 0,01$). Результати дисперсійного аналізу підтвердили суттєві відмінності в поглядах на розвиток футболу з боку зацікавлених сторін, батьків і тренерів ($F = 47,724, p < 0,001$).

Висновки. Дослідження підкреслює провідну роль тренерів, зацікавлених сторін та батьків у розвитку дитячо-юнацького футболу, наголошуючи на необхідності покращення тренерської освіти, інвестицій з боку зацікавлених сторін та збалансованої залученості батьків. Міцна співпраця є ключовим чинником сталої та цілісної моделі розвитку.

Ключові слова: розвиток дитячо-юнацького футболу, тренер, залученість батьків, зацікавлені сторони.

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Anthropometric Aspects and Athletic Performance in Women's Tennis

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Abstract

Background. In recent decades, the evolution of female athletes' physical characteristics in women's tennis has sparked interest, particularly regarding the influence of stature on success in Grand Slam tournaments.

Objectives. This study aimed to analyze the evolution of the height of the finalists and winners of the women's Grand Slam tournaments in order to evaluate whether height is a determining factor for success and whether this impact varies according to the playing surfaces.

Materials and methods. A retrospective analysis of the heights of the finalists and winners from 2000 to 2024 in the four major Grand Slam tournaments was conducted: Australian Open, Roland-Garros, Wimbledon and U.S. Open. The data were compared between tournaments on fast surfaces (Australian Open and U.S. Open) and tournaments on slower surfaces (Roland-Garros and Wimbledon).

Results. The findings revealed a significant increase in the average height of the finalists and winners in tournaments on fast surfaces, with a clear increase in the average height starting from 2021. In tournaments on slower surfaces, the average height showed more stable or slightly declining trends, suggesting that other physical qualities, such as mobility and endurance, may be key to success. In particular, the average height of the Australian Open and U.S. Open finalists indicated a continuous increase, while at Roland-Garros and Wimbledon the fluctuations were more contained.

Conclusions. This study confirms that stature has a significant impact on success in Grand Slam tournaments, but this effect is mediated by the playing surface. In tournaments on fast surfaces, greater stature seems to give a competitive advantage, while on slower surfaces other physical factors can play a role. Future perspectives include exploring other anthropometric variables and analyzing their evolution in relation to the needs of modern gaming.

Keywords: anthropometric aspects, performance, women's tennis.

Introduction

Women's tennis is one of the most followed and practiced sports globally, characterized by a remarkable variety of styles of play and athletes from different traditions and cultures (Temesi et al., 2024). In recent decades, the level of competition on the professional circuit has grown exponentially, bringing to light numerous factors that determine the success of an athlete, including physical

skills, technique, mental preparation (Scamardella et al., 2020), adaptability to different playing surfaces and metabolic factors (Latino et al., 2021). Among the physical characteristics, one of the most debated is the stature (Söğüt, 2018). Height has always been considered an important element in many sports, especially those where strength, power and the ability to cover large areas of the field are essential. From a biomechanical point of view, height has advantages in terms of levers, which are directly reflected in the power of the shots. The serve, for example, can benefit from smoother movement and greater ball acceleration due to the natural angle that height provides (Erlandson et al., 2008).

Another aspect where stature can be an advantage concerns the coverage of the court. The height also allows for more extension in defensive phases, improving court coverage and making it easier to execute more powerful return shots, particularly against opponents who use faster or angled shots. In particular, this advantage manifests itself in volleys and in the net game, where the stature allows for better positioning and a greater ability to anticipate the opponent's trajectories. Physical endurance is another element that can benefit from a larger stature. Taller female athletes often have more muscle mass, which allows them to better sustain their efforts during long matches and reduce the risk of injury (Sanchez-Munoz et al., 2007; Scamardella et al., 2020).

However, tall stature also comes with disadvantages that cannot be overlooked. The first disadvantage concerns the biomechanical challenges related to greater height. Very tall athletes, in fact, have to deal with more complex and difficult movements, especially when it comes to rapid changes of direction. The length of the levers, especially the legs and arms, makes the movements more difficult to perform as quickly and smoothly as shorter athletes. This can negatively affect speed and agility, two key characteristics in tennis, where the ability to react quickly to opponents' shots is crucial (Pradas et al., 2021). In addition, a larger stature means a greater load on the joints, especially on the knees and ankles, which have to support the weight of a larger and heavier body. Tall players may be more prone to muscle and joint injuries, especially during explosive movements or sudden changes of direction. These injuries can compromise the stability and continuity of the game, negatively affecting performance, especially in the long run (Fett et al., 2020).

Another negative aspect concerns the difficulty in controlling the ball. Taller athletes, despite having greater power in hitting the ball, may find it difficult to maintain precise control, especially on shots of greater finesse such as the drop shot or the net game. The coordination and dexterity required to execute these precise shots can be more difficult to achieve than shorter athletes, who generally have greater agility and a better ability to manipulate the ball (Elce et al., 2017).

In other words, in a highly competitive environment like the current one, stature can give an advantage in attacking phases, especially in powerful shots and serve. However, in an increasingly dynamic and fast-paced game, speed of movement and the ability to adapt to different playing surfaces are just as crucial. Tall athletes, despite having advantages in power and court coverage, may find it difficult to adapt to the demands of a game that requires quick changes of direction and precision in shots. The speed of execution of shots is a key factor for success in modern women's tennis, and shorter players, who can often move with greater agility and speed, are able to counter the power of taller opponents thanks to their ability to anticipate the game (Baiget et al., 2023).

The role of height in tennis has been extensively explored in the context of men's tennis, but relatively little has been written about the specific implications for women's tennis. There is a lot of evidence to suggest that height can significantly affect tennis performance with many studies emphasizing the importance of height for serve power and court coverage (Kovalchik, 2018). However, despite the growing interest in the physical characteristics of female

players in women's tennis, the existing literature has not yet clearly outlined whether height is a determining factor for success in women's tennis elite, or whether other factors, such as speed and technique, can compensate for any physical disadvantages related to height.

Some studies have examined the correlation between height and performance in women's tennis, but without reaching definitive conclusions. It has been observed that tall stature in male tennis players has a positive impact on serve, power, and the ability to cover the court, but the same studies have not focused specifically on female athletes (Luna-Villouta et al., 2021). In addition, some authors suggest that height may affect not only serve power, but also physical endurance, given that taller female athletes tend to have greater muscle mass (Yasin et al., 2010).

In women's tennis, players such as Serena Williams, Venus Williams and Maria Sharapova, who possess considerable stature compared to the average of their peers, have often been the subject of discussion regarding the advantage that their height can confer. Some authors argue that stature is a crucial element for the success of these players, particularly for the power and speed of their serve (Sánchez-Pay et al., 2021). Söğüt (2019) examines serving results and the returns to it are better for tennis players with greater height. Santisteban (2024) in a broader anthropometric spectrum highlights how the speed of the stroke is greater with reference to the height and length of the upper limbs.

However, more recent studies tend to downplay the importance of height as a determining factor, placing an emphasis instead on speed, coordination, and game strategy (Parpa et al., 2022). This evidence raises the question that stature, while representing a physical advantage in some aspects of the game, may not be sufficiently relevant to determine success at the elite level, where other factors such as technique and mental preparation may play a predominant role.

Despite the extensive research that has examined the correlation between height and performance in men's tennis, relatively few studies have focused on the specific implications of height in women's tennis. Most of the available literature on the factors that influence success in women's tennis tends to focus on variables such as speed, agility, and technique, rather than height. Although some studies have analyzed height as a possible advantage in elite female athletes, the available evidence is still limited, with results varying depending on the methodological approach and sample size. In addition, there is a dearth of longitudinal research examining how stature affects performance over the course of a career, considering the evolution of athletes' physical and technical abilities (Chapelle et al., 2023). Another significant gap in the literature concerns the absence of a comparative analysis between athletes of different heights and their performance in different types of playing surfaces (grass, clay, concrete). Physical characteristics and the type of playing surface could interact in different ways with stature, affecting performance in complex and not yet fully understood ways. For example, on faster surfaces such as concrete, speed may be a more important factor than the physical power that comes from higher altitude. The dynamism of the game and the rapid changes of direction could in fact reduce the advantages associated with tall stature, while on slower surfaces such as

clay, where resistance and court coverage are crucial, stature could be more advantageous (Olcucu, & Vatansever, 2015).

In light of the gaps in the existing literature, this study aims to examine the extent to which height influences the performance of elite female tennis players, as well as the mechanisms through which it may determine success in this sport. The analysis will focus on the distribution of heights among Grand Slam finalists from 2000 to 2025, investigating the potential relationship between height and the likelihood of winning the final. Furthermore, the study will explore the role of court surface (hard, grass, or clay) in shaping athletes' performance in relation to their height. Lastly, it will examine differences in the average height of finalists based on the specific characteristics of each tournament, comparing, for instance, the U.S. Open with Wimbledon.

Materials and Methods

Study Design

The study followed a qualitative-descriptive design that integrated statistical analysis with the collection of data from official sources, in order to gain a deep understanding of the distribution and influence of height in finalist tennis players of Grand Slam tournaments.

Sample

The reference sample was made up of 200 athletes, representing all the finalist tennis players of the Grand Slam tournaments from 2000 to 2025. This sample includes both winners and non-winners. The analysis was divided by year and by tournament, allowing a global and annual view of the data.

Procedure

The data was collected exclusively from official sources, in particular from the WTA Tennis (<https://www.wtatennis.com/>) website, which offers comprehensive information on the finalists and winners of Grand Slam tournaments from 2000 to 2025. For each tournament, the following were considered:

- Each year's finalists for each Grand Slam tournament.
 - Each year's winners for each Grand Slam tournament.
- Main variables:
- Height of the athletes: Measured in centimeters for each player.
 - Torneo del Grande Slam: U.S. Open, Australian Open, Roland Garros, e Wimbledon.
 - Playing surface: clay (Roland Garros), hard courts (U.S. Open, Australian Open), grass (Wimbledon).
 - Final result: Victory or defeat in the final.

Statistical Analysis

In the context of this study, several statistical tests were used in order to analyze data on the height of finalist tennis players in Grand Slam tournaments, with the aim of understanding whether there are significant differences between non-winning winners and finalists and exploring the influence of the playing surface. Each statistical test was

chosen to answer a specific research question and to analyze the relationships between the variables appropriately.

One of the main tests used was the t-Student test for independent samples, which was applied to check whether there are significant differences in height between the winning and non-winning finalists. This statistical test is particularly useful when you want to compare the averages of two separate groups, in this case the tennis players who won and those who did not win the final. The t-Student test allows you to determine whether the differences between the averages of the two groups are statistically significant or whether they can be attributed to chance. In our case, this test was applied separately for each Grand Slam tournament and for each playing surface, in order to identify whether stature can actually influence the odds of winning, taking into account contextual variables related to the type of surface (e.g., grass, clay or hard courts).

Another fundamental test used was analysis of variance (ANOVA). This test was used to compare the averages of tennis players' heights between different tournaments and playing surfaces. The ANOVA is particularly useful when you want to compare the averages of more than two groups, such as in the case of different Grand Slam tournaments and different playing surfaces. This test tests whether the differences between the averages of several groups are statistically significant. In the context of our study, ANOVA was applied to determine whether differences in finalist heights varied significantly depending on the tournament (e.g., U.S. Open vs. Wimbledon) or surface (hard, grass, clay). In other words, the ANOVA helped explore whether the playing surface and the type of tournament significantly influence the physical characteristics of female athletes, such as height.

In addition to inferential testing, descriptive statistical models were also used to provide a general overview of the tennis players' height data and distributions. These models made it possible to calculate summary statistics such as the mean, median, standard deviation, and interquartile range for each group of tennis players. Descriptive models are critical to gaining an initial understanding of the data and to observe trends, concentrations, or possible outliers (extreme values) in athletes' heights. These basic statistics were used to visualize the distribution of heights and to identify any patterns or anomalies in the collected data.

Results

The following analysis explores the relationship between height and success in elite women's tennis, examining the height distribution of Grand Slam finalists and winners from 2000 to 2025, as well as the influence of court surface and the specific characteristics of each tournament.

Australian Open Finalists

The analysis of the heights of the finalists shows a fluctuating trend, with phases of growth and decrease. In the period considered, the minimum height recorded was 166 cm, while the maximum reached 186 cm. Since 2016, the range has narrowed, with values ranging from a minimum of 173 cm to a maximum of 183 cm. Overall, the average height of the finalists was 177 cm, but the general trend shows a

slight decrease over time. However, starting from 2022, a reversal of this trend has been observed: the average height has increased, with an absolute minimum of 180 cm and a maximum of 184 cm, signaling greater uniformity in values and a possible evolution in the physical characteristics of the finalist athletes (Fig. 1).

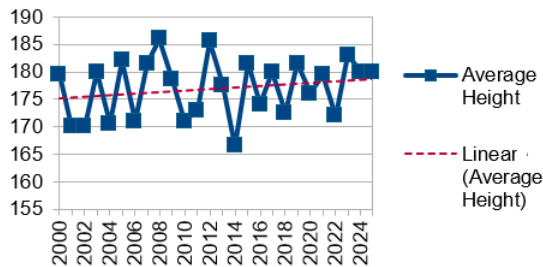


Fig. 1. Height of Australian Open

Australian Open Winners

The data show alternating growth and decrease trends, with an absolute minimum of 168 cm and an absolute maximum of 189 cm. The average height of the winners, in the period analyzed, stands at 176 cm, with a general increasing trend. In particular, from 2023 a steady increase in the average height is observed, suggesting an evolution in the physical characteristics of the winners (Fig. 2).

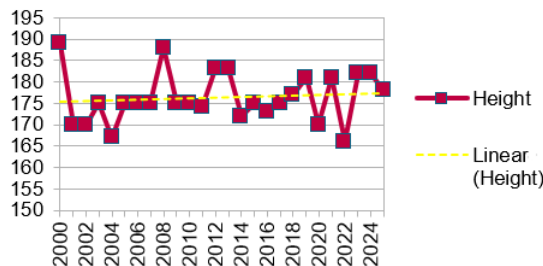


Fig. 2. Height of Australian Open winners

U.S. Open Finalists

The graph (Fig. 3) shows alternating decreasing and ascending strokes. In particular, the height of the finalists fluctuates between an absolute minimum of 169 cm and a maximum of 188 cm. However, since 2021, this range has narrowed, with a minimum of 177 cm and a maximum of 183 cm. The average height of the finalists in the period considered is 176 cm, with a general decreasing trend.

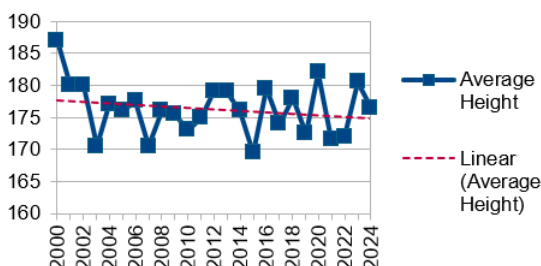


Fig. 3. Height of U.S. Open finalist

U.S. Open. Winners

The graph (Fig. 4) shows height values ranging from an absolute minimum of 167 cm to a maximum of 189 cm, with curves that alternate ascending, decreasing and stationary strokes. However, since 2019, this range has narrowed, with a minimum of 170 cm and a maximum of 184 cm. The average height of the winners in the period analyzed is 176 cm, with a trend that follows the linear average almost perfectly. From 2021 to 2024, the graph indicates a clear increase in the average height of the winners.

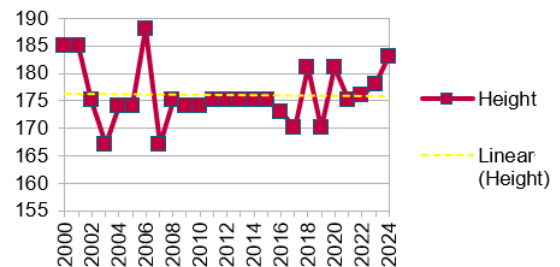


Fig. 4. Height of U.S. Open winners

Roland Garros Finalist

The graph (Fig. 5) shows an alternating trend, with both increasing and decreasing traits. Height values vary from an absolute minimum of 169 cm to a maximum of 183 cm. In the period considered, the average height of the finalists stands at 175 cm, with a slight tendency to decline.

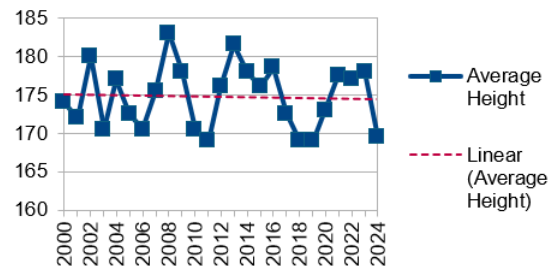


Fig. 5. Height of Roland Garros finalist

Roland Garros Winners

The graph (Fig. 6) of the winners of Roland Garros shows an alternating trend, with stationary, increasing and decreasing traits. The values range from an absolute minimum of 166 cm to an absolute maximum of 188 cm. As of 2021, the maximum value is reduced to 176 cm, which corresponds to the absolute minimum. The average height of the winners is around 175 cm, with a clear upward trend.

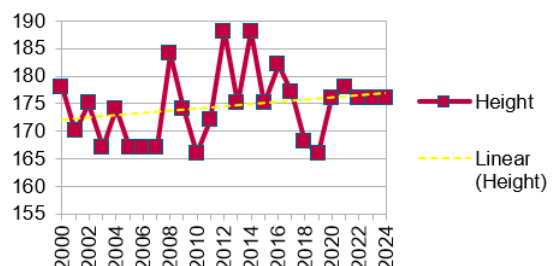


Fig. 6. Height of Roland Garros winners

Wimbledon Finalist

The graph (Fig. 7) shows an alternating trend, with phases of growth and decrease, as well as two-year periods of stability. In the period analyzed, the absolute minimum height recorded is 169 cm, while the absolute maximum reaches 187 cm. The average height of the finalists stands at 177 cm, but the general trend shows a clear decline. In addition, a significant reduction in both the maximum and minimum values (from 172 cm to 169 cm) is observed.

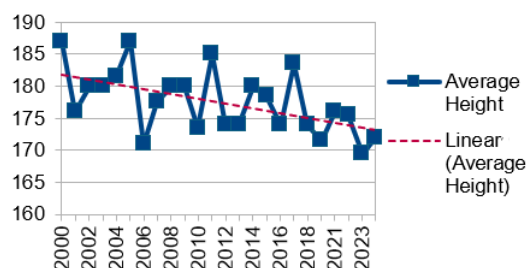


Fig. 7. Height of Wimbledon finalist

Wimbledon Winners

The trend of the graph (Fig. 8) clearly shows phases of growth and decrease, with some two-year periods of stability. In particular, the absolute maximum value recorded is 188 cm, while the absolute minimum is 166 cm. The average height of the winners of the tournament stands at 178 cm, while the trend line shows a clear decline over time.

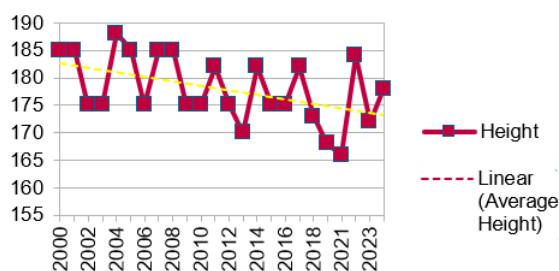


Fig. 8. Height of Wimbledon winners

Grand Slam Winners

The graph (Fig. 9) shows both increasing and decreasing variations over the period considered. In particular, the absolute maximum value reaches 184 cm, while the absolute minimum stands at 171 cm. The average height of Grand Slam winners in the analyzed time interval is 176 cm. The trend line is almost stable, overlapping the average value just mentioned.

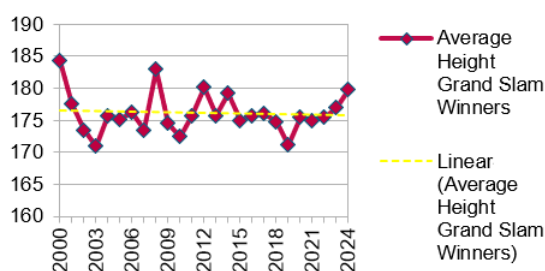


Fig. 9. Height of Grand Slam winners

T-TEST

The statistical analysis highlighted significant differences between the average height of the groups considered and the reference mean of 180 cm. The key findings are as follows:

The negative t-values indicate that the average heights of the analyzed groups are generally lower than the reference mean.

The Cohen's d suggests that the effect size is moderate (between -0.4 and -0.6) for some groups and strong (up to -1.0) for others.

Notably, the finalists and winners of Roland Garros show the largest effect size ($d \approx -1.0$), suggesting that this tournament tends to have shorter athletes compared to the other Grand Slams.

The Wimbledon winners present the smallest difference from the reference mean ($d \approx -0.4$), indicating that this tournament features slightly taller players than the others.

Table 1. The statistical analysis differences between the average height of the groups considered and the reference mean of 180 cm

Group	Mean Height (cm)	t-value	Cohen's d
Australian Open Finalists	177	-4.24	-0.6
Australian Open Winners	176	-5.66	-0.8
U.S. Open Finalists	176	-5.66	-0.8
U.S. Open Winners	176	-5.66	-0.8
Roland Garros Finalists	175	-7.07	-1.0
Roland Garros Winners	175	-7.07	-1.0
Wimbledon Finalists	177	-4.24	-0.6
Wimbledon Winners	178	-2.83	-0.4
Grand Slam Winners	176	-5.66	-0.8

These results suggest that height may play a significant role in competition, with some differences between tournaments, likely related to the characteristics of the playing surfaces.

ANOVA

To determine whether differences in the heights of finalists varied significantly depending on the tournament or playing surface, an analysis of variance (ANOVA) was conducted. This statistical test allows for the evaluation of significant differences among multiple groups by comparing variability between groups to variability within groups. Below are the ANOVA results for the comparison between different tournaments and playing surfaces.

The analysis of variance (ANOVA) confirmed that there are significant differences in the average heights of finalists depending on the tournament played and the playing surface.

When comparing the different Grand Slam tournaments (Australian Open, U.S. Open, Roland Garros, and Wimbledon), the F-value = 14.18 with $p < 0.00005$ indicates that the observed variations in height are not random but reflect a significant trend. This suggests that each tournament may favor athletes with different physical characteristics, likely in relation to playing conditions and the most effective strategies for competing at that level.

Similarly, the playing surface also proved to be a determining factor. ANOVA returned an F-value = 16.26 with $p < 0.00005$, confirming that the average heights of finalists vary significantly among hard courts, clay courts, and grass courts. This result suggests that the physical attributes required to excel on each surface differ and that height may represent an advantage or disadvantage depending on the context.

In summary, these results support the hypothesis that height is a relevant parameter in elite women's tennis, but its impact varies according to playing conditions. While tournaments like the Australian Open seem to favor taller athletes, in other contexts, such as Roland Garros, players with different physical characteristics may emerge, likely to better adapt to the specific demands of the surface.

Discussion

The aim of this study was to analyze the evolution of the average height of Grand Slam finalists and winners over time, with the aim of determining whether height is a key factor for success in elite women's tennis and whether its impact varies according to the playing surface.

Starting from the analysis of the Australian Open finalists and winners, the data show a clear trend of the average height of the finalists increasing, which has gone from 175 cm to 179.5 cm. This suggests that, in a context characterized by a fast surface, height can be a decisive element to compete at the highest level. This hypothesis is further supported by the observation that, starting from 2022, the average height of the finalists has reached higher values both in the absolute minimum (180 cm) and in the absolute maximum (184 cm), reducing the range of variation and confirming a constant growth trend. The same trend can be seen among the winners of the tournament, with an increase in average height, suggesting that the selection of taller athletes may represent a competitive advantage on this surface. These data are consistent with the initial hypotheses of the study.

On the other hand, the analysis of the finalists and winners of the U.S. Open reveals an opposite trend. The average height of the finalists has progressively decreased, from 177 cm in 2000 to 175 cm in 2024. However, from 2021 onwards, the range of variation between the minimum and maximum values has reduced, suggesting that in recent years a balance has been achieved between height and other physical qualities decisive for the game. This trend is only partially consistent with the initial assumptions. As for the winners, after a phase of fluctuating values until 2008, a stabilization is observed for almost a decade, coinciding with the dominance of one of the Williams sisters. From 2021 onwards, however, there is a new increase in the average height of the winners, confirming the expected general trend.

In the case of Roland Garros, the average height of the finalists shows a slight decrease, stabilizing at around 175 cm. This suggests that, on a surface such as clay, technical skills and endurance may have a greater weight than height. However, analyzing the winners, a different trend emerges: the average height has increased from 173 cm to 176.5 cm, with a stabilization starting from 2021 at a maximum value of 176 cm. This could indicate that although height is not the predominant factor on this surface, there is still a minimum threshold that is considered advantageous. This is in line

with previous research showing that clay favors baseline play and physical endurance rather than the power and speed typical of hard surfaces (Reid et al., 2016).

The Wimbledon analysis, on the other hand, shows a decreasing trend in the average height of the finalists, which went from 183 cm to 177 cm in the period considered. This result, reinforced by the reduction of minimum and maximum absolute values, suggests that the characteristics required to excel on grass may differ from those of other surfaces. The same trend can be seen in the winners, with a decrease in average height and the presence of stationary periods. This trend, apparently at odds with initial assumptions, can be explained by considering the specificities of the herb, which reward speed, responsiveness and effective serve rather than tall stature (Liu et al., 2016).

Finally, the analysis of the Grand Slam winners in the period under consideration shows a general stability of the average height of around 176 cm, a value that coincides with the general trend. This suggests that while height is not constantly increasing in elite women's tennis, it is still a minimum requirement to compete at the highest level. However, starting from 2021, an increase in average height is observed, a figure that is at least partly consistent with the initial hypotheses of the study.

According to the authors of the study, the evolution of the average height of Grand Slam finalists and winners is the result of a natural selection process linked to the specific technical needs of each playing surface. The growth in stature in Australian Open and U.S. Open winners confirms the hypothesis that greater height can promote a more aggressive game, in line with previous studies highlighting the importance of height in serve and groundstrokes on hard surfaces (Giles & Reid, 2020). The stabilization of heights at Roland Garros suggests that other skills, such as mobility and endurance, may be more decisive for success on clay (Söğüt, 2018). For Wimbledon, the downward trend may indicate that quickness and the ability to adapt to an uneven surface are more important than stature (Vaverka & Cernosek, 2013). Overall, these results confirm what has emerged from the existing literature, in fact although height is a competitive advantage in tennis, its impact varies depending on the playing conditions and the strategies adopted by the athletes. Analyzing the data from the study allows significant conclusions to be drawn about the role of height in elite women's tennis, but it is important to consider both the strengths and limitations of the research.

This study has several strengths that strengthen its validity and scientific relevance. First, the analysis was conducted over a wide period of time, allowing us to identify evolutionary trends in the stature of the finalists and winners of Grand Slam tournaments. This longitudinal approach allows for a better understanding of the influence of height in elite women's tennis and to assess any adaptations due to changes in playing surfaces, playing style or athletic training patterns. In addition, the study uses objective and measurable data, ensuring a solid empirical basis for the conclusions drawn. Another strength is the integration with the existing literature, which allows the results to be contextualized and compared with previous research on the role of height in professional tennis.

However, the study also has some limitations. A first aspect to consider is that the analysis focuses exclusively on

height, without examining other anthropometric and biomechanical factors that could affect performance, such as limb length, muscle mass or body composition. In addition, the height of female athletes has been considered as an independent factor, while in reality success in tennis depends on a complex set of variables, including technical, tactical, psychological and athletic skills. Another limitation is individual variability: although the finalists and winners of Grand Slam tournaments have been analyzed, the sample may not be entirely representative of the entire population of professional tennis players. Finally, the study does not take into account possible future evolutions in the style of play or physical characteristics of female athletes, which could further change the relationship between height and success in tennis.

Despite these limitations, the study makes a significant contribution to understanding the role of height in elite women's tennis and paves the way for further research that could deepen the link between physical parameters and performance, including biomechanical and tactical aspects.

Conclusions

The study explored the evolution of the heights of Grand Slam finalists and winners, with the aim of understanding whether stature decisively influences success in elite women's tennis and how this impact can vary depending on the playing surface. Analysis of the data showed that height is indeed a relevant factor, but its role appears to be differentiated according to the specific characteristics of the tournament surfaces. The increase in average height in the Australian Open and U.S. Open finalists and winners, on fast surfaces, suggests that height can give advantages in terms of power and court coverage in these contexts. Conversely, data from Wimbledon and Roland Garros, with more stable or declining trends, suggest that on slower surfaces, such as grass and clay, other factors, such as mobility and endurance, may have a greater weight.

The stability observed in the average heights of Grand Slam tournament winners, with a slight increase since 2021, supports the hypothesis that there is an optimal minimum height to compete at world level, but also that the variability of physical characteristics remains a fundamental element in sporting success.

The practical implications of these results suggest that female athletes could be selected not only on the basis of their height, but also considering other physical and technical parameters, in particular those more related to the specificities of the surfaces on which they play. In addition, the findings contribute to a greater understanding of how women's tennis is evolving, with stature trends mirroring the game's adaptation to modern demands.

Despite the conclusions obtained, this study also raises questions about aspects that are still little explored. A future perspective could be to include additional anthropometric parameters, such as limb length or body composition, to better understand how these factors may interact with height to influence performance. In addition, it would be interesting to examine the evolution of the physical characteristics of female athletes in relation to athletic preparation and developments in tennis-specific training techniques.

Another line of research could focus on the analysis of the evolutionary trends in the stature of female athletes of

different nationalities, to assess whether there are significant differences based on cultural or geographical factors. In addition, a deeper analysis of the interactions between physical characteristics and game tactics, such as the ability to adapt to different surfaces or the speed of the serve, could offer new insights for coaches and athletes in choosing training models.

Finally, longitudinal studies that also consider the future performance of female athletes could enrich the understanding of the evolution of physical characteristics over the course of a tennis player's career, thus offering further perspective on the impact of height and other physical parameters on success in elite women's tennis.

Conflict of Interest

The authors declare that there is no conflict of interest.

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Антропометричні аспекти та спортивна результативність у жіночому тенісі

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 9 с., 1 табл., 9 рис., 24 джерел.

Історія питання. В останні десятиліття питання еволюції фізичних характеристик спортсменок у жіночому тенісі стало предметом зацікавленості, особливо щодо впливу зросту на досягнення успішних результатів на турнірах Великого шлему.

Мета дослідження. Це дослідження мало на меті проаналізувати еволюцію показників зросту фіналісток і переможниць жіночих турнірів Великого шлему задля визначення того, чи є зріст вирішальним фактором успіху і чи варіюється цей вплив залежно від типів покриття ігрового майданчика.

Матеріали та методи. Проведено ретроспективний аналіз показників зросту фіналісток та переможниць з 2000 по 2024 рік на чотирьох головних турнірах Великого шлему: Відкритий чемпіонат Австралії, Ролан-Гаррос, Вімблдон і Відкритий чемпіонат США. Порівняння даних проводилось між турнірами на швидких покриттях (Відкритий чемпіонат Австралії та Відкритий чемпіонат США) та турнірами на повільних покриттях (Ролан-Гаррос та Вімблдон).

Результати. Результати дослідження встановили значне підвищення показників середнього зросту фіналісток та переможниць турнірів на швидких покриттях, причому чітке збільшення цього показника спостерігається з 2021 року. У турнірах на повільних покриттях показник середнього зросту мав стабільніші тенденції або дещо знижувався, що свідчить про ключову роль у досягненні успішних результатів інших фізичних якостей, таких як рухливість і витривалість. Зокрема, показник середнього зросту фіналісток Відкритого чемпіонату Австралії та Відкритого чемпіонату США демонстрував постійне зростання, тоді як на турнірах Ролан-Гаррос та Вімблдоні коливання показників виявилися стриманішими.

Висновки. Проведене дослідження підтверджує, що зріст має суттєвий вплив на досягнення успішних результатів у турнірах Великого шлему, однак цей вплив опосередковується типом покриття ігрового майданчика. У турнірах на швидких покриттях вищий зріст, ймовірно, надає конкурентну перевагу, в той час як на повільних покриттях свою роль можуть відігравати інші фізичні фактори. Подальші перспективи включають вивчення інших антропометричних змінних та аналіз їхньої еволюції відповідно до потреб сучасної гри.

Ключові слова: антропометричні аспекти, результативність, жіночий теніс.

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Proactive Decision-Making of Physical Education Teachers in Enhancing Competence through Further Studies: A Comparative Study

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Abstract

Objectives. This study aimed to compare physical education (PE) teachers' proactive decision-making to improve competence through further studies.

Materials and methods. A quantitative approach with a comparative descriptive design was used in the study. This design was established to test whether there were significant differences in views among Public Civil Servants (PCS), Government Employees with a Work Agreement (GEWA), and Contract Employee (CE) teachers in making proactive decisions for further study as an effort to improve their competence. The participants were 252 PE teachers in East Nusa Tenggara Province, Indonesia. They were divided into three groups, each consisting of 52 PCS teachers, 110 GEWA teachers, and 90 CE teachers. The research instrument (18 statement items) was developed using the Proactive Decision-Making concept with six main indicators: systematic identification of objectives, systematic identification of alternatives, systematic search for information, using a decision radar, taking initiative, and striving for improvement. Testing the validity and reliability of the instrument was conducted using outer model analysis with SmartPLS version 4.0.9.9. The hypothesis testing process involved using the Kruskal-Wallis analysis and Dunn's post-hoc test with the SPSS program version 29.

Results. The research instrument successfully met the validity and reliability tests, marked by loading factor values = 0.804-0.932, Cronbach's alpha = 0.875-0.928, composite reliability = 0.875-0.928, AVE = 0.699-0.811, discriminant validity = 0.699-0.811, and HTMT = 0.836-0.900. Furthermore, the Kruskal-Wallis test found significant differences among the three groups of teachers in PDM who were to participate in further studies. Another fact is that post-hoc testing found significant differences only in the CE-GEWA and CE-PCS teacher groups, while GEWA-PCS did not demonstrate such differences.

Conclusions. Among the three groups of participants, contract/honorary teachers have a more temporary employment status and show the lowest level of proactiveness in making decisions to pursue further studies as an effort to improve their competencies.

Keywords: competency development, further education, lifelong learner, physical education teacher competence, proactive decision-making.

Introduction

58 years ago, Roundy (1967) reported general areas that explain the lack of competence of physical education teachers. Four main problems of teacher competence were identified. First, managing classes with large student populations. Second, assessing and reporting student learning progress. Third, handling adaptive physical education. Fourth, evaluating the effectiveness of learning.

Although it has been reported for a long time, the problems above are still obstacles for teachers in the current century and may continue. This fact explains that teacher competence is a series of skill attributes that are always dynamic, so the homework of today's and future teachers is to be involved in various competency development activities so that they can guarantee and orchestrate meaningful and impactful learning for their students.

With various technological advances and the openness of information in the field of education and learning today, it is still found that the competence of physical education teachers is relatively lacking. For example, teacher competence when

describing student orientation to problems, organizing students to learn, guiding investigations, presenting work results, and evaluating problem-solving (Safi'i et al., 2023). In addition, physical education teachers also have difficulty in dividing teaching tasks according to student abilities, implementing strategies to optimize student practice (Blegur et al., 2023), and difficulty using digital competence in implementing various methodologies to develop and support collaborative networks (Martínez-Rico et al., 2021).

The competence of physical education teachers in planning learning is still problematic. In this context, they cannot yet choose appropriate and clear learning objectives and cannot identify appropriate learning procedures or models to achieve the educational and learning objectives set (Altaweel & AlJa'afreh, 2017). It means they do not have a good grasp of pedagogical and professional competencies in detail (Anwar et al., 2020). If the problems of teacher competence are not immediately addressed, it will have an impact on their declining performance (Halimahturrafiah et al., 2023; Hartika et al., 2020; Siri et al., 2020) and, of course, hamper the fulfilment of the need for quality human resources who can play a professional role in society (Wiyono et al., 2018).

In response to the above problems, researchers have attempted to conduct investigations and promote various ways to improve teacher competence. For example, improving the pedagogical competence of teachers based on teaching materials (Hastuti et al., 2022) or participating in seminars (theoretical, problematic, psychological and pedagogical), workshops, teaching hours, pedagogical advice, festivals of pedagogical ideas, master classes and others (Mischenko et al., 2024), and being active in continuing professional development (Ramanan et al., 2024). Even considering the significance of the competence of physical education teachers in the future, Blegur et al. (2024) applied an integrated learning model to improve the competence of prospective teachers, including teaching skills, analytical thinking skills, academic integrity, and transformational leadership.

In the current study, the researcher aims to highlight proactive decision-making (PDM) in teachers' competency development through further studies. Proactive decision-making refers to individual decision-making oriented towards a future vision so that they prepare themselves to meet the criteria of that vision. The vision navigates them to act more proactively (Siebert et al., 2020; Siebert & Kunz, 2016) by designing more organized and projective learning behaviours to achieve that vision. For example, a previous study by Azma et al. (2011) found that teachers (both male and female) were not interested in continuing their studies, the reason being that they had obtained better managerial positions in schools (such as principals). However, recently, further studies have become a necessity for teachers. Maviş Sevim and Akın (2021) found that teachers began to realize and decide to take further studies because they helped them in professional development, changed their approach to evaluating student learning activities, were more confident, and improved their performance.

Moreover, other studies have reported that the reasons teachers want to pursue further studies are for self-development, academic careers, professional development, deepening knowledge in their field of expertise, and becoming more specialized in carrying out their profession

(Faruk Vural & Başaran, 2021), as well as helping them improve their intrapersonal and interpersonal qualities (Smothers et al., 2022). Another organizational benefit is that teachers' further studies have an impact on school development (Postholm & Rokkones, 2015) because they are empowered to become leaders and mentors, thus influencing the implementation of a supportive educational climate (Teves & Ubayubay, 2024) to create differentiated, active, participatory, interactive, and impactful learning classes.

Behind the enthusiasm for developing the competence of physical education teachers to pursue further studies, they face financial challenges in funding their education. This problem is caused by different teacher salaries among teacher categories (Public Civil Servant, Government Employee with a Work Agreement, and Contract Employee), the distance of the campus that provides further education, government and foundation regulation issues, and other internal socio-economic conditions. Teachers have hopes and goals to develop competence through further studies, but they must think hard to find scholarships and ensure that other economic needs are not disrupted. Given that financing is a prominent aspect of the college experience and can be a catalyst for—or a barrier to—their future academic success (Wu & Corpus, 2023).

Therefore, this study aims to compare the PDM of teachers (from teacher categories with different salary backgrounds) to improve competence through further studies.

Materials and Methods

Study Participants

Participants were 252 Physical Education teachers in East Nusa Tenggara Province, Indonesia. Each was distributed into three participant groups. First, the Public Civil Servant (PCS) group consisted of 52 people ($M \pm SD$ age = 39.2 ± 6.5), with details of males = 46 people (88.5%) and females = 6 people (11.5%). Second, the Government Employee with a Work Agreement (GEWA) group consisted of 110 people ($M \pm SD$ age = 34.5 ± 4.6), with details of males = 90 people (81.8%) and females = 20 people (18.2%). Therefore, the Contract Employee (CE) group consisted of 90 people ($M \pm SD$ age = 31.5 ± 4.3), with details of males = 74 people (82.2%) and females = 16 people (17.8%). They were determined using the convenience sampling technique so that participants were willing to respond to the research instrument (using Google forms) voluntarily (Mahardika et al., 2024; Scholtz, 2021).

Study Organization

This study used a quantitative approach with a comparative (descriptive) design, where the researcher did not treat the three groups of participants. The researcher chose this design to test whether there are significant differences in views among PCS, GEWA, and CE teachers in making competency development decisions through further study. Further study is one way for teachers to update their competencies and, at the same time, open access or professional networks with their colleagues and experts. In addition, they are also constrained by welfare issues (salary),

so they need to make proactive decisions to follow further study. Given that the three groups of participants have different welfare (salaries), this design can help researchers provide recommendations that suit the needs of teachers so that they still have the goal of developing competency through further study.

The research procedure began with researchers compiling instruments (with the help of Google forms) in a five-point Likert scale format by referring to the PDM concept and indicators from Siebert and Kunz (2016). The instrument was then distributed to participants from November to February 2025. The collected data on teachers' proactive decision-making for further studies is tabulated and categorized into three participant groups, with any respondents not meeting the study's exclusive criteria being eliminated. Next, the researcher conducted an outer model analysis to test the validity and reliability of the instrument, followed by a descriptive analysis to examine the mean and standard deviation. A comparative test using the Kruskal-Wallis method is then performed to analyze differences among the three participant groups, concluding with a post-hoc Dunn analysis to address the study's hypothesis.

Instrument

The design of the proactive decision-making instrument for the follow-up study of participants refers to the concept and six dimensions of PDM developed by Siebert and Kunz (2016). First, the systematic identification of goals is the basis for systematically creating alternatives, guiding methodical information searches, and decision planning. Second, systematic identification of alternatives, namely identifying alternatives, increases the likelihood that individuals will achieve their goals by improving proactive cognitive skills. Third, a systematic search for information, namely relevant values, guides information collection in decision-making. Fourth, using a decision radar, individuals can frame their decisions strategically and proactively consider other decisions in a future-oriented way. Fifth, proactive individuals take the initiative in decision-making by actively shaping their environment. Sixth, striving for improvement, proactive individuals strive to create meaningful impact by striving for improvement in decision-making situations. This research instrument consists of 18 items with a composition of three statement items representing each indicator.

Participants responded to the instrument using a five-point Likert scale (disagree-strongly agree).

Statistical Analysis

Testing the validity and reliability of the PDM instrument for further study of participants using outer model analysis assisted by Microsoft Excel and SmartPLS version 4.0.9.9 applications. The criteria for testing the validity and reliability of the research variable instrument are as follows: (1) loading factor (λ) >0.70 (Hair Jr et al., 2019; Hulland, 1999; Kay Kwong, 2013), (2) discriminant validity Heterotrait-monotrait Ratio of Correlations (HTMT) <0.90 (Henseler et al., 2016) and Average Variance Extracted (AVE) >0.50 (Henseler et al., 2016), and (3) Cronbach alpha and composite reliability >0.70 (Hair Jr et al., 2020; Henseler et al., 2016).

Descriptive analysis aims to profile the decision to continue studying from the three groups of participants. Meanwhile, the Kruskal-Wallis test was used because the data from the three participant groups did not meet the normality test criteria (Kolmogorov-Smirnov). Namely, each participant group had a significance value <0.001 . The Kruskal-Wallis test aims to find differences in participant perceptions of their proactive decision-making to participate in further studies. Furthermore, the Dunn post-hoc test was conducted to see which participant groups had significant differences among the three groups by looking at the significance value (sig. <0.05). The entire data collection process used the help of Google forms, Microsoft Excel, and SPSS version 29.

Results

The results of this study are reported sequentially, starting with testing the instrument's validity and reliability using outer model analysis from SmartPLS, then descriptive analysis and non-parametric statistical testing of Kruskal-Wallis.

Validity and Reliability of the Research Instrument

The results of the outer model analysis confirm that the 18-item PDM design successfully meets the parameters for convergent validity, with a loading factor >0.70 (ranging

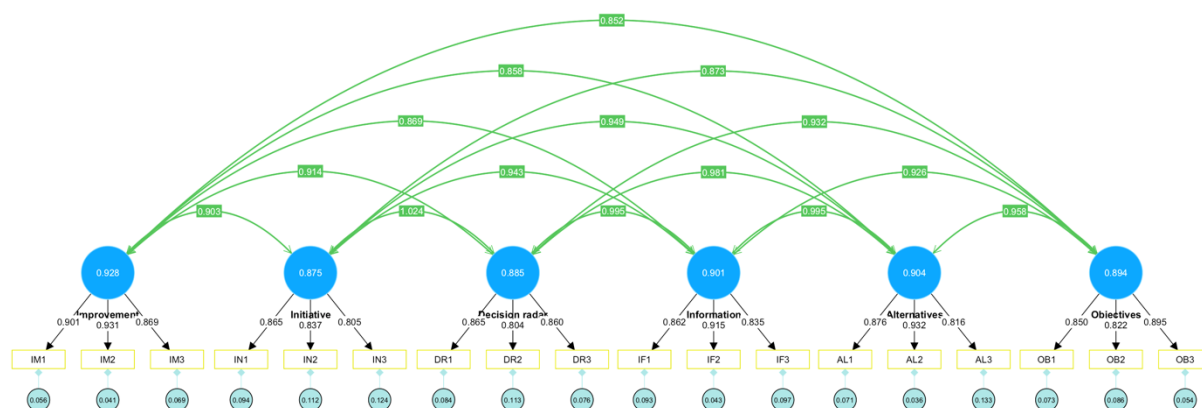


Fig. 1. Path diagram of research instruments

from 0.804 to 0.932) (Hair Jr et al., 2019; Hulland, 1999; Kay Kwong, 2013) (see Figure 1). The lowest loading factor, 0.804, was found in the item “Further studies help me consider career development in my current decision-making.” Meanwhile, the highest loading factor, 0.932, was observed in the item “Further studies help me carefully identify ways to achieve my goals.”

Continuing with the reliability testing, it was found that the PDM indicators had a Cronbach alpha value > 0.70 (0.875-0.928), a composite reliability value > 0.70 (0.875-0.928) (Hair Jr et al., 2020; Henseler et al., 2016). The AVE test proved the discriminant validity value > 0.50 (0.699-0.811) (Henseler et al., 2016), and the HTMT value also met the test parameters with a value range of 0.836-0.900 (Henseler et al., 2016) (see Table 1). Based on the results of the validity and reliability test of the instrument, it is concluded that the 18 items developed to test the decision-making of further studies of physical education teachers fulfil their function and consistency as a measuring tool because they can manifest the actual situation.

Table 1. Validity and Reliability of the Research Instrument

Indicators	Cronbach alpha	Composite reliability	AVE	HTMT
Objectives	0.894	0.892	0.733	0.856
Alternatives	0.904	0.902	0.767	0.876
Information	0.901	0.901	0.759	0.871
Decision radar	0.885	0.881	0.712	0.844
Initiative	0.875	0.875	0.699	0.836
Improvement	0.928	0.928	0.811	0.900

Descriptive Analysis

Table 1 shows that objective and improvement indicators are still the “idol” indicators, consistently receiving the highest responses among the three participant groups. If we examine further, the data shows that the CE teacher group gave a lower PDM response than the other two participant groups (PCS and GEWA). It could be concluded that CE teachers decided to continue their studies (to develop competence) because of regulatory demands or other external pressures (more reactive).

Table 2. Descriptive analysis

Indicators	Group participant (M ± SD)		
	PCS (n = 52)	GEWA (n = 110)	CE (n = 90)
Objectives	4.6 ± 0.5	4.6 ± 0.5	4.5 ± 0.5
Alternatives	4.6 ± 0.6	4.5 ± 0.5	4.4 ± 0.6
Information	4.5 ± 0.6	4.5 ± 0.5	4.4 ± 0.6
Decision radar	4.5 ± 0.6	4.5 ± 0.5	4.4 ± 0.6
Initiative	4.5 ± 0.7	4.5 ± 0.6	4.4 ± 0.6
Improvement	4.6 ± 0.6	4.6 ± 0.5	4.5 ± 0.5

Kruskal-Wallis analysis

Considering the normality test results (see the explanation of the normality test in statistical analysis), the researcher

conducted a Kruskal-Wallis test (non-parametric). The results prove that the asymptotic significance value for PDM is <0.001 (<0.05), so it is concluded that there is a significant difference between the three groups of participants (see Table 3).

Table 3. Kruskal-Wallis analysis

Test statistics ^{a,b}	
Kruskal-Wallis H	64.587
df	2
Asymp. sig.	<0.001

a. Kruskal Wallis Test

b. Grouping Variable: Group

The results of Dunn's post-hoc test (see Table 4) prove that two adj. sig. values are <0.05, namely in the CE and GEWA teacher group pairs (0.000) and the CE-PCS group pairs (0.000). Thus, there is a significant difference in PDM when further studies are undertaken between the CE and GEWA teacher groups and CE and PCS. It proves that only two groups of teachers (PCS and GEWA) are proactive in undertaking further studies as an integral part of their efforts to maintain and improve competence.

Table 4. Post-hoc Dunn test (Pairwise comparisons of grup)

Sample 1 - Sample 2	Test statistic	Std. error	Std. test statistic	Sig.	Adj. sig. ^a
CE-GEWA	74.223	10.245	7.245	<0.001	0.000
CE-PCS	79.859	12.556	6.360	<0.001	0.000
GEWA-PCS	5.635	12.131	0.465	0.642	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.

Asymptotic significances (2-sided tests) are displayed. The significance level is .050.

a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

Discussion

Summary of Research Hypotheses

The results of this study successfully answered the main hypothesis that there are significant differences in PDM attitudes among the three groups of teachers, namely PCS teachers, GEWA teachers, and CE teachers. Where significant differences were found between PCS-CE and GEWA-CE teachers when compared to CE teachers, PCS and GEWA teachers were more proactive in making decisions about further study to improve competence and including by formulating competency development goals to create alternatives systematically, identifying alternatives to improve competence, oriented towards future competence, actively shaping their environment to improve competence, and striving to improve their competence.

Comparison with Published Data

Teachers must have competencies in the form of knowledge, skills, and behaviors that are internalized and

mastered when carrying out their professional duties (Hartika et al., 2020) because mastery of competencies is one of the keys to the success of physical education teacher learning (Hartono et al., 2024). Undeniably, teacher competencies always change following the learning needs of students that continue to develop over time. That means teachers who are competent today do not guarantee that they will also be competent in the future. Therefore, in teachers' efforts to maintain and guarantee their competencies, they must take the initiative and also be proactive in updating a set of skills periodically to be in line with the learning needs of their students (Blegur et al., 2024), including implementing differentiated learning (Blegur & Hardiansyah, 2024; Colquitt et al., 2017; Sitovsky et al., 2019).

Given the increasing complexity of students' learning needs and the clearer pathways for teacher career development, teachers are beginning to realize and agree that further studies help them in professional development, change their approach to evaluating students' learning activities, become more confident, improve their performance (Maviş Sevim & Akin, 2021), self-development efforts, pursue academic careers, professional development, deepen knowledge in their fields of expertise, and become more specialized in carrying out their profession (Faruk Vural & Başaran, 2021). Not only that, but further studies also help them improve their intrapersonal and interpersonal qualities (Smothers et al., 2022), increase their chances of getting promoted to become school leaders and mentors for colleagues (Campanilla, 2024; Teves & Ubayubay, 2024), and influence teachers' social lives (Lisansüstü et al., 2021).

Contract/honorary teachers show lower PDM for further studies. It is because they have salary compensation that is not equal to PCS and GEWA teachers, even though compensation affects teacher performance (Maharani et al., 2022). The salaries of contract/honorary teachers are still below standard (not by the performance they produce), resulting in reduced guarantees of their safety, health, and welfare. This welfare problem (economic) makes them more likely to look for side jobs to meet their family's needs rather than making proactive decisions to improve their competence through further studies (Faruk Vural & Başaran, 2021; Rosmanida et al., 2022). Therefore, if school management wants to improve their teachers' performance, they can provide adequate compensation accompanied by a clear and systematic career advancement pattern (Ismawati et al., 2023).

Significance of research findings

While there is limited literature explaining the PDM of physical education teachers to pursue further studies, the results of this study provide new insights into PDM preferences among teachers with different employment statuses. Career development is an important part of teaching, so teachers must continue proactively developing their competencies (Celik, 2017). The results of this study can be a basis for policymakers to provide wider teacher education scholarships and design empowerment programs for teachers in decision-making to foster high commitment (sense of ownership) in their professional learning (Mohammad Nezhad & Stolz, 2024). Universities also need to increase financial assistance and educational sponsorship

to open up greater opportunities for teachers to continue their education (Amahido, 2024).

Practical Application

The practical application of the results of this study is to design a teacher competency development program so that teachers with various economic problems still have a positive attitude to improve their competence. Not only that, providing scholarships and/or conducting training and mentoring to teachers so that they are competitive in selecting scholarships provided by the government, private sector, foundations, universities and so on, both from within and outside the country, is very necessary and actively designing policies that support improving the welfare of contract/honorary teachers so that they can be more proactive in improving their competence. The goal is for them to become individuals who are inspired by the desire always to be proactive and take new initiatives and are flexible in adapting dynamic teaching approaches and adjusting their teaching actions to the characteristics and uniqueness of their students (Francesco et al., 2019).

Future Research Prospects

The results of this study have provided a significant picture of the differences between civil servants, government employees with a work agreement, and contract/honorary teachers regarding PDM in further studies for improving competence. There is still much room for further research into factors that can improve the decision-making competence of further studies of physical education teachers in Indonesia. Further research prospects should be focused on more in-depth testing of other factors that can influence teacher PDM, such as teaching experience, teacher professional education received, teacher professional certification, and the influence of transformational leadership and school culture. In addition, further research opportunities can also examine whether there are differences in proactive decision-making styles between teachers who teach in schools with different characteristics, such as public and private schools or schools in urban and rural areas.

Conclusions

This study successfully answered the research objectives, where there were significant differences between the three groups of participants in PDM to develop competencies through further study (asympt. sig. <0.001). It means that each group of teachers has a different tendency to make proactive decisions about their competency development. The most significant differences were found in the PCS and CE teacher groups and GEWA and CE teachers. On the other hand, no significant differences were found between PCS and GEWA teachers. It means that of the three groups of participants, contract/honorary teachers have a more temporary work status, showing the lowest level of proactivity in making decisions for further study.

PCS and GEWA teachers, as state's apparatus employees, have guaranteed salaries and careers and tend to be more stable in making decisions related to self-development through further study. They have greater access to various training and education programs, encouraging them to

be more proactive in planning and making decisions to improve their competencies. On the other hand, job uncertainty factors, a salary system that is not yet nationally equal, and limited resources are the main obstacles for contract/honorary teachers in planning long-term competency development. Finally, it is important to initiate policies supporting contract/honorary teachers to develop their competencies, one of which is increasing access and incentives for further study.

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Conflict of Interest

If the authors have any conflicts of interest to declare.

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Проактивне ухвалення рішень викладачів фізичного виховання щодо підвищення компетентності через подальше навчання: Порівняльне дослідження

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 8 с., 4 табл., 1 рис., 43 джерела.

Мета дослідження. Метою цього дослідження було провести порівняльний аналіз проактивного ухвалення рішень викладачів фізичного виховання (ФВ) щодо поліпшення рівня компетентності шляхом реалізації подальшого навчання.

Матеріали та методи. У дослідженні застосовано кількісний підхід із порівняльним дескриптивним методом. Зазначений метод розроблено для перевірки того, чи існують значні відмінності в поглядах між викладачами державних закладів (ВДЗ), державними службовцями за трудовою угодою (ДСТУ) та викладачами, які працюють за контрактом (ВК), щодо ухвалення проактивних рішень для подальшого навчання з метою підвищення їхньої компетентності. Учасниками дослідження були 252 викладачі фізичного виховання з провінції Східна Нуса Тенгара, Індонезія. Їх було розділено на три групи, кожна з яких складалася з 52 викладачів ВДЗ, 110 викладачів ДСТУ та 90 викладачів за контрактом. Інструмент дослідження (18 тверджень) було розроблено з використанням концепції проактивного ухвалення рішень з шістьма основними показниками: систематичне визначення цілей, систематичне визначення альтернатив, систематичний пошук інформації, використання радару для реалізації рішень, прояв ініціативи та прагнення до вдосконалення. Перевірка валідності та надійності інструменту проводилася за допомогою аналізу зовнішніх моделей із використанням програмного забезпечення SmartPLS версії 4.0.9.9. Процес перевірки гіпотез передбачав використання аналізу Краскала-Уолліса та post-hoc тесту Данна за допомогою програми SPSS версії 29.

Результати. Дослідницький інструмент ефективно відповідав критеріям валідності та надійності, про що свідчать значення коефіцієнта навантаження = 0,804-0,932, альфа Кронбаха = 0,875-0,928, комплексної надійності = 0,875-0,928, AVE = 0,699-0,811, дискримінантної валідності = 0,699-0,811 та HTMT = 0,836-0,900. Крім того, критерій Краскала-Уолліса виявив значущі відмінності між трьома групами викладачів у проактивному ухваленні рішень, які мали брати участь у подальших дослідженнях. Інший факт полягає в тому, що post-hoc тестування встановило суттєві відмінності лише в групах викладачів, які працюють за контрактом та державних службовців за трудовою угодою, а також викладачів за контрактом та працівників державних закладів, тоді як група ДСТУ-ВДЗ не продемонструвала таких відмінностей.

Висновки. Серед трьох груп учасників дослідження встановлено, що контрактники/почесні викладачі мають більшою мірою тимчасовий статус зайнятості та демонструють найнижчий рівень проактивності в ухваленні рішень для проведення подальшого навчання з метою покращення своїх професійних компетенцій.

Ключові слова: розвиток компетентності, подальша освіта, людина, яка навчається впродовж життя, компетентність викладача фізичного виховання, проактивне ухвалення рішень.

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Programming of the Training Process for Qualified Female Volleyball Players in the Preparatory Period of the Annual Training

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Abstract

Objectives. The study aimed to experimentally prove the efficiency of building structural formations of the training process for qualified female volleyball players within the preparatory period of the annual training cycle on the basis of programming.

Material and methods. Qualified female volleyball players from the first category of the student team ($n = 16$) participated in the experiment, with an average age of 19.56 ± 0.81 years. The research was carried out during 2023-2024 and included two stages of a sequential pedagogical experiment — ascertaining and formative. The formative experiment provided the development and experimental substantiation of efficiency for introducing interconnected programs of structural formations in the training process of qualified volleyball players within the preparatory period of the annual macrocycle (programs of the period, meso- and microcycles, training sessions and their parts — training tasks). The criteria of efficiency were the indicators of physical fitness (a standing high jump, a throw of a stuffed ball of mass 1 kg with two hands from behind a head on a distance, a shuttle run of 30 m according to the scheme 9-3-6-3-9 m, and a run “herringbone” of 92 m), functional fitness (fat content and muscular components in the body, relative maximum consumption of oxygen), technical and tactical fitness (the coefficient of efficiency of technical and tactical actions).

Results. At the formative stage of the experiment, in comparison with the ascertaining one, the volume of training loads was reduced by 5.7 % (from 5725 to 5400 min), the load value was reduced by 4.9 % (from 41804 to 39742 points), the intensity of loads was increased by 1.4 % (from 7.3 to 7.4 points/min); the share of general preparatory (from 44.0 to 40.3 %) and introductory (from 37.3 to 34.3 %) exercises was decreased, however, due to this the share of specially-preparatory (from 6.8 to 8.3 %) and competitive (from 11.9 to 16.1 %) exercises was increased; the share of loads of mixed aerobic-anaerobic (from 40.9 to 41.3 %), anaerobic alactate (from 5.0 to 9.2 %) and anaerobic glycolytic orientation (from 3.7 to 4.3 %) was increased due to the decrease of the share of aerobic orientation loads (from 50.4 to 45.3 %).

Conclusions. The findings suggest that the construction of the training process for qualified female volleyball players within the preparatory period on the basis of programming promoted statistically reliable ($p < 0.050$) improvements in the following indicators: physical fitness in the limits of 1.90–5.12 %, functional fitness in the limits of 1.43–1.65 %, as well as technical and tactical fitness — by 4.92 %. The results obtained in this study confirm the efficiency of the program developed for the preparatory period of qualified volleyball players and allow to recommend it for practical application in the training process of volleyball teams.

Keywords: program, training task, microcycle, mesocycle, training means, training loads.

Introduction

Modern trends in the development of team game sports dictate the need to find relevant approaches to building and

improving the training process (Leibo et al, 2021; Brynzak et al, 2023; Kostiukevych et al, 2019). On the one hand, this is due to a certain stabilization and consolidation of the results of competitive activity, which significantly increases competition both in the national and international arenas (Bezmylov et al, 2022; Sobol et al, 2024; Shlonska, Borysova, Yakusheva, 2024). In addition, the approaches typical of past decades, which involved a constant increase in the volume,

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magnitude and intensity of training loads, have exhausted their efficiency, as they have reached certain maximum indicators (Lima et al, 2024; Winther et al, 2024). Thus, a further increase in training loads will be accompanied only by the exhaustion of the functional reserves of the athletes' body (Bompa, Buzzichelli, 2018; Platonov, 2018; Rebelo et al, 2024). Given this, in today's conditions there is an urgent need to optimize the training process at different stages of annual and long-term training (Adamchuk et al, 2023).

Experts consider programming to be one of the most promising areas of optimizing the training process at the present stage, which is considered mainly in terms of programmed learning and training programming (Adamchuk et al, 2022; Hidayah et al, 2024; Shynkaruk et al, 2025). The first approach is based on a motor learning scheme based on a step-by-step algorithm. It allows consistently, on the basis of previously formed motor skills and abilities, to form new ones, gradually complicating the tasks for athletes to bring them to a new level of mastery of technical techniques. Programmed learning is reflected in the works on table tennis (Stasyuk et al, 2021), volleyball (Verbitskiy, Pityn, & Karatnyk, 2023), badminton (Hidayat et al, 2023) and other game sports.

The idea of programming different aspects of training is widely used in sports. In particular, Ihsan et al (2025) conducted a systematic review of studies aimed at the development and implementation of multidirectional strength training programs in order to develop an integrated approach to planning trainings with a focus on the development of muscle strength. In the work of Guo et al (2023), a rowing training program was developed and experimentally substantiated based on modeling of load modes, depending on the characteristics of competitive activity.

Training programs of different duration and focus are actively implemented in the practice of training athletes in game sports (Ihsan et al, 2024). In particular, in the work of Narayanan et al (2025) the influence of a 12-week program of plyometric and Tabata training on the functional state of the cardiovascular system of football players is studied. The study by Türkarslan and Deliceoglu (2024) substantiates the effectiveness of implementing a 6-week plyometric training program for the development of agility, speed and high-speed and power abilities in young football players. The 12-week TRX and plyometric training program developed by Muriyedath et al (2025) is aimed at improving the physical and functional fitness of volleyball players. Irvan et al (2024) suggest a 12-week combined circular Tabata program and study its impact on the physical fitness of young squash players.

At the same time, despite the wide representation of the problem of programming in sports in the existing scientific heritage, we note the narrow focus of the outlined studies, since the generalization of available literature sources showed mainly the accentuated influence of certain means of the outlined programs on certain aspects of the preparedness of athletes. At the same time, an integrated approach to programming of the training process of athletes in team game sports requires a detailed justification (Kostiukevych et al, 2024). Also, a number of advantages testify in favor of the use of the programming method in the construction of the training process, in particular, the possibility of implementing targeted management influences and the formation of training effects due to the clear regulation of

the load components (Adamchuk et al, 2021; Shchepotina, Kostiukevych, Asauliuk et al, 2021).

Hypothesis of the research: It was assumed that the construction of structural formations of the training process of qualified female volleyball players within the preparatory period of the annual macrocycle on the basis of programming would contribute to the optimization of training of female athletes by regulating the components of the load and implementing targeted management influences.

The purpose of the research - experimentally to prove the effectiveness of construction of structural formations of the training process for the qualified female volleyball players within the preparatory period of the annual cycle of training on the basis of programming.

Material and Methods

Participants

The experiment involved qualified first category female volleyball players of the student team of Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University ($n=16$), whose average age was ($M \pm SD$) 19.56 ± 0.81 years. The research was approved by the Ethics Committee of the Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, and all procedures were in accordance with the Declaration of Helsinki. Informed consent was obtained from the participants to take part in this experiment.

Organization of the Research

The research was carried out during 2023-2024 and included two stages of a sequential pedagogical experiment – ascertaining and formative. During the ascertaining experiment the construction of the training process of the researched qualified female volleyball players within the preparatory period was carried out on the basis of traditional planning. At this stage we carried out the control of means of preparation of female athletes (general preparatory, special preparatory, introductory and competitive) and loads of different orientation (aerobic, mixed aerobic-anaerobic, anaerobic alactate, anaerobic glycolytic) by means of the method of chronometry (Kostiukevych et al, 2019; Shchepotina, Kostiukevych, Asauliuk et al, 2021). At the same time, the amount of training load was determined by the Load Value Coefficient (LVC, points) according to the formula (Adamchuk et al, 2022, 2023; Shchepotina, Kostiukevych, Asauliuk et al, 2021):

$$LVC = \sum t_e \times I_e, \quad (1)$$

where: t_e - exercise duration (min); I_e - exercise intensity (points), depending on the heart rate (114 bpm - 1 point, 120 bpm - 2 points, 126 bpm - 3 points, 132 bpm - 4 points, 138 bpm - 5 points, 144 bpm - 6 points, 150 bpm - 7 points, 156 bpm - 8 points, 162 bpm - 10 points, 168 bpm - 12 points, 174 bpm - 14 points, 180 bpm - 17 points, 186 bpm - 21 points, 192 bpm - 25 points, 198 bpm - 33 points).

The intensity of the training load was determined by the intensity coefficient (IC, points/min) according to the formula (Adamchuk et al, 2021; Shchepotina, Kostiukevych, Asauliuk et al, 2021):

$$IC = \frac{LVC}{T}, \quad (2)$$

where: T is the duration of the training session (min).

The influence of the applied training loads on the preparedness of female players was investigated. In particular, the dynamics of physical fitness indicators was studied by the results of pedagogical testing. The tests recommended by experts as informative were used (Kozina, Polishchuk, Polishchuk, 2023; Sieroń, Stachoń, Pietraszewska, 2023), including, for the definition of the manifestation of high-speed and power abilities – a standing high jump (cm) and a throw of a stuffed ball of mass 1 kg with two hands from behind a head on a distance (kg); for determination of agility in interrelation with speed – shuttle run 30 meters according to the scheme 9-3-6-3-9 m (s); for determination of high-speed endurance in interrelation with agility – a run “herringbone” 92 m (s). The influence on the functional fitness of volleyball players was investigated by the results of morphofunctional diagnostics. The body composition was studied using the OMRON BF 511 (works on the principle of bioelectrical impedance) (Shchepotina, Kostiukevych, Drachuk et al, 2021), which involved determining the percentage (%) of fat and muscle components in the body of female athletes. In addition, an indirect method based on the linear dependence on the indicator of physical performance PWC170, determined by bicycle ergometry, calculated the relative maximum oxygen consumption (VO_{2max} , ml/min/kg) according to the formula (Kostiukevych et al, 2021; Kenney, Wilmore, Costill, 2022):

$$VO_{2max} = \frac{1.7 \times PWC_{170} + 1240}{m}, \quad (3)$$

where: m - body weight of the volleyball player (kg).

The dynamics of technical and tactical preparedness of volleyball players was studied by the results of pedagogical observation of training games of female athletes with the following determination of the efficiency coefficient of technical and tactical actions (EC, c.u.) according to the formula (Shchepotina, Kostiukevych, Asauliuk et al, 2021; Kostiukevych et al, 2021):

$$EC = \frac{\sum TTA_s}{\sum TTA_t}, \quad (4)$$

where: $\sum TTA_s$ is the sum of successfully performed technical and tactical actions during one game; $\sum TTA_t$ – the total

number of technical and tactical actions performed during one game.

The formative experiment envisaged the development and experimental substantiation of efficiency of the introduction of interconnected programs of structural formations of the training process of qualified volleyball players within the preparatory period of the annual macrocycle (programs of the period, meso- and microcycles, training sessions and their parts - training tasks), components of a load in which were developed with an orientation on the directed formation of training effects (urgent, delayed and cumulative) in female athletes. So, the program of the preparatory period of qualified female volleyball players is presented in fig. 1 and included four components: the characteristic and structure of training loads, quantitative and qualitative (criteria of efficiency) indicators of the training process.

The implementation of the offered program of construction of the training process for the qualified volleyball players in the preparatory period was carried out by development and introduction of programs of smaller structural formations - mesocycles (table 1), microcycles, training sessions and tasks (table 2) in which the components of loading - volume, value, intensity, ratio, etc. were clearly regulated.

Thus, the smallest structural unit of programming of the training process of qualified volleyball players was the program of the training task. Accordingly, the programs of training tasks made up the programs of training sessions.

Statistical analysis. The processing of numerical data on indicators of physical, functional and technical and tactical preparedness of the researched qualified female volleyball players at the stages of the pedagogical experiment was carried out on the basis of descriptive statistics (Byshevets et al, 2019; Bai, Bai, 2021; Jones, 2022). The mean value (M) and standard deviation (SD) were determined. Statistical reliability in the difference of indicators of preparedness of sportswomen at the stages of the pedagogical experiment was determined by the parametric Student's t-test. The difference between indicators was considered reliable at $p < 0.050$ and $p < 0.010$. The preliminary data were checked for compliance with the normal distribution of results by the W-criterion of Shapiro-Wilk.

Results

The processing of data of the ascertaining and formative stages of the pedagogical experiment allowed to compare parameters of training loads. First of all, we note a decrease by 5.7 % (from 5725 to 5400 min) in the volume of training loads in the preparatory period at the formative stage, compared to the ascertaining stage. The load value was also reduced by 4.9 % (from 41804 to 39742 points). However, the intensity of loads increased by 1.4 % from 7.3 pts/min at the ascertaining stage to 7.4 pts/min at the formative stage (fig. 2).

We note the redistribution of training tools (fig. 3). In particular, at the formative stage of the experiment, compared to the ascertaining stage, the share of general preparatory (from 44.0 to 40.3%) and introductory (from 37.3 to 34.3%) exercises was reduced, however, due to this, the share of special preparatory (from 6.8 to 8.3%) and competitive (from 11.9 to 16.1%) exercises was increased.

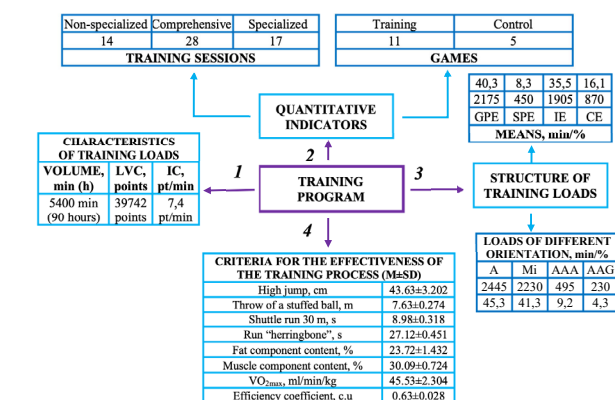


Fig. 1. The program of the training process of qualified volleyball players in the preparatory period: LVC – load value coefficient; IC – intensity coefficient; Means: GPE – general preparatory exercises, SPE – special preparatory exercises, IE – introductory exercises, CE – competitive exercises; Loads of different orientation: A – aerobic orientation, Mi – mixed aerobic-anaerobic orientation, AAA – anaerobic alactate orientation, AAG – anaerobic glycolytic orientation; VO_{2max} – relative maximum oxygen consumption

Table 1. Program for building mesocycles of qualified female volleyball players during the preparatory period

Mesocycles			Retractable	Basic developmental	Control and preparatory	Pre-competitive
Microcycles			1 retractable	1 hitting	ordinary	1 introductory
			2 retractable	2 hitting restorative	hitting restorative	2 introductory restorative
Characteristics of training loads	Volume, min (hours)		1080 min (18 hours)	1380 min (23 hours)	1440 min (24 hours)	1500 min (25 hours)
	Load value coefficient, points		5941 points	10802 points	11417 points	11582 points
	Intensity coefficient, pts/min		5.5 pts/min	7.8 pts/min	7.9 pts/min	7.7 pts/min
Quantitative indicators of the training process	Training sessions, number	non-specialized	6	3	3	2
		specialized	2	5	6	4
		comprehensive	6	7	6	9
	Games, number	training	1	4	4	2
		control	-	-	1	4
Structure of training loads	Training means	general preparatory, min (%)	655 min (60.6 %)	605 min (43.8 %)	485 min (33.7 %)	430 min (28.7 %)
		special preparatory, min (%)	-	135 min (9.8 %)	205 min (14.2 %)	110 min (7.3 %)
		introductory, min (%)	365 min (33.8 %)	480 min (34.8 %)	510 min (35.4 %)	550 min (36.7 %)
		competitive, min (%)	60 min (5.6 %)	160 min (11.6 %)	240 min (16.7 %)	410 min (27.3 %)
		aerobic, min (%)	730 min (67.6 %)	675 min (48.9 %)	515 min (35.8 %)	525 min (35.0 %)
		Loads of different orientation	mixed aerobic-anaerobic, min (%)	305 min (28.2 %)	520 min (37.7 %)	580 min (40.3 %)
	anaerobic alactate, min (%)		45 min (4.2 %)	120 min (8.7 %)	235 min (16.3 %)	95 min (6.3 %)
	anaerobic glycolytic, min (%)		-	65 min (4.7 %)	110 min (7.6 %)	55 min (3.7 %)

Since the level of fitness of volleyball players is also influenced by the distribution of training loads of different orientation, we will compare their ratio at the ascertaining and formative stages of the pedagogical experiment (fig. 4).

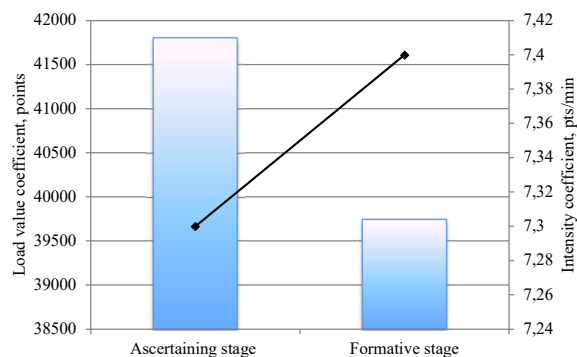


Fig. 2. The total value (points) and average intensity (points/min) of training loads of qualified female volleyball players in the preparatory period at the ascertaining and formative stages of the experiment: ■ – load value coefficient (points); —●— intensity coefficient (points/min)

In particular, at the formative stage of the experiment, in comparison with the ascertaining one, we note an increase in a share of loads of the mixed aerobic-anaerobic (from 40.9 to 41.3 %), anaerobic alactate (from 5.0 to 9.2 %) and anaerobic glycolytic (from 3.7 to 4.3 %) orientation at the expense of

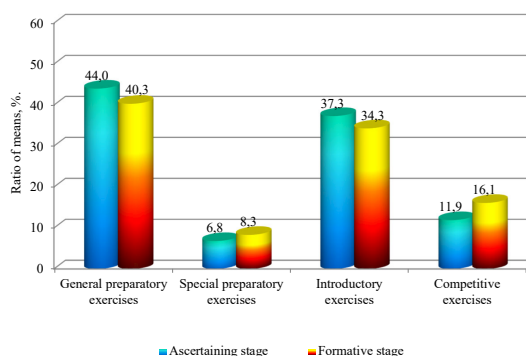
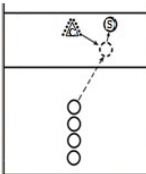


Fig. 3. Correlation of training means of qualified female volleyball players in the preparatory period at the ascertaining and formative stages of the experiment, %

Table 2. Program of training task for improvement of physical fitness of qualified female volleyball players

Content	Title: special coordination and speed and power training. Code: PT.19. Objective: improvement of special coordination fitness of volleyball players in connection with high-speed and power qualities. Venue: sports hall. Form of organization: team training. The program of the training task is performed in the first half of the main part of the training session in basic mesocycles. It is advisable to perform exercises on both sides of the site to increase motor density. The character of intervals of rest is passive.			 S – setter; C – coach; ○ – player; -> – direction of movement						
Algo-rhythm	Content of the individual steps of the training task program	t	Components of the load							
			I	RI	HR	LVC				
1 st step	Jumping from a full crouch with a stuffed ball weighing 1 kg in hands. Perform 3 series of 8-10 jumps.	3 min	H-M	45-60 s	174-186 bpm	51 points				
2 nd step	S.P.: a group of players in a column, one by one, in zone 6, the coach with the balls in zone 3, the binder between zones 2 and 3. The coach throws balls to the front line, which the players in turn have to take in the fall and bring to the binder, who returns the balls back to the coach. Perform 7-10 falls.	5 min 30 s	H	30-45 s	162-174 bpm	66 points				
3 rd step	Throws of stuffed balls weighing 1 kg in pairs over the net; players are placed on the lines of attack. Perform 10-15 throws.	2 min	H	30-45 s	162-168 bpm	22 points				
4 th step	Same as step 2, only the coach throws balls to the back line, which the players, moving backward, should take with two hands on top in a low stance with a fall and bring to the binder. Perform 5-7 falls.	3 min 30 s	H	30-45 s	162-174 bpm	42 points				
5 th step	Walking. Breathing exercises. Preparation for the next task.	1 min	L	-	120-132 bpm	3 points				
Training work parameters										
Characteristics of training loads				Structure of training loads						
				Training means, min (%)		Multidirectional loads, min (%)				
Volume, min	LVC, points	IC, pts/min	GPE	SPE	PE	CE	A	Mi	AAA	AAG
15 min	184 points	12.3 pts/min	6 min (40.0 %)	9 min (60.0 %)	-	-	1 min (6.7 %)	11 min (73.3 %)	3 min (20.0 %)	-

Notes: t – time; I – intensity: M – maximum, H – high, L – low; RI – resting intervals; HR – heart rate; LVC – load value coefficient; IC – intensity coefficient; S.P. – starting position; Means: GPE – general preparatory exercises, SPE – special preparatory exercises, IE – introductory exercises, CE – competitive exercises; Loads of different orientation: A – aerobic orientation, Mi – mixed aerobic-anaerobic orientation, AAA – anaerobic alactate orientation, AAG – anaerobic glycolytic orientation

the decrease in a share of loads of the aerobic orientation (from 50.4 to 45.3 %).

An important step on the way to the substantiation of efficiency of programming of the training process for the qualified volleyball players was the definition of dynamics of indicators of preparedness of the researched female athletes under the influence of the applied training loads at the ascertaining and formative stages of the pedagogical experiment. Since indicators of physical, functional, technical and tactical preparedness of the qualified volleyball players at the stages of the pedagogical experiment corresponded to the normal distribution of results of measurements by the W-criterion of Shapiro-Wilk (table 3), it gave us grounds to use the parametric Student's t-test to define statistical reliability in the difference of results.

Comparison of indicators of physical, functional, technical and tactical preparedness of qualified volleyball players obtained at the beginning of the ascertaining stage with the results obtained at the beginning of the formative stage (table 4), showed the absence of significant differences in the display of high-speed and power abilities by female athletes in indicators of a standing high jump ($t = 0.22$; $p = 0.826$) and a throw of a stuffed ball with two hands from behind the head ($t = 0.35$; $p = 0.731$), in a manifestation of agility in interrelation with speed by an index of a shuttle run 30 m ($t = 0.10$; $p = 0.919$), in a manifestation of high-speed endurance in interrelation with agility by an index of a run "herringbone" 92 m ($t = 0.15$; $p = 0.812$), in a component composition of a body weight by indexes of a fat content ($t = 0.37$; $p = 0.714$) and muscular ($t = 1.03$; $p = 0.312$)

Table 3. Determination of conformity to the normal distribution of indicators of physical, functional, technical and tactical preparation of qualified female volleyball players at the ascertaining (AS, n=16) and formative (FS, n=16) stages of the pedagogical experiment

Sl. No	Research indicators	Stage of the experiment	Statistical indicators				Description
			In the beginning		At the end		
			W	p	W	p	
1	A standing high jump, cm	AS	0.954	0.503	0.945	0.371	normal
		FS	0.959	0.580	0.962	0.620	normal
2	Throwing a stuffed ball with two hands from behind the head, m	AS	0.896	0.108	0.921	0.152	normal
		FS	0.917	0.136	0.915	0.122	normal
3	Shuttle run 30 m (9-3-6-3-9 m), s	AS	0.911	0.109	0.922	0.163	normal
		FS	0.920	0.114	0.930	0.214	normal
4	Run “herringbone” 92 m, s	AS	0.980	0.937	0.972	0.827	normal
		FS	0.985	0.982	0.988	0.992	normal
5	Fat component content, %	AS	0.952	0.492	0.949	0.438	normal
		FS	0.919	0.136	0.931	0.228	normal
6	Muscle component content, %	AS	0.924	0.167	0.935	0.254	normal
		FS	0.922	0.165	0.941	0.322	normal
7	VO ₂ max, ml/min/kg	AS	0.990	0.996	0.971	0.823	normal
		FS	0.959	0.624	0.946	0.410	normal
8	Efficiency coefficient, conventional units	AS	0.968	0.747	0.957	0.521	normal
		FS	0.938	0.272	0.912	0.100	normal

components, in aerobic productivity of an body by the relative index of maximum oxygen consumption ($t=0.15$; $p=0.885$), in quality of performance of technical and tactical actions by the efficiency coefficient ($t=0.45$; $p=0.656$). Since the initial results did not differ significantly, it allowed us to continue the pedagogical experiment with obtaining objective data on the efficiency of programming of the training process for the qualified volleyball players.

Repeated measurements carried out at the end of the preparatory period showed significant statistically reliable improvements of the majority of the studied indicators of physical, functional, technical and tactical preparation of qualified volleyball players at the stage of the formative

experiment (table 5) when the construction of the training process within the preparatory period was carried out on the basis of programming. In particular, we note the improvement of physical fitness of the researched female athletes by indicators of a standing high jump by 5.12 % ($t=2.24$; $p=0.033$), a throw of a stuffed ball with two hands from behind a head – by 4.17 % ($t=2.63$; $p=0.013$), a run "herringbone" 92 m – by 1.90 % ($t=3.39$; $p=0.034$), functional preparation by indicators of fat component content – by 1.44 % ($t=2.42$; $p=0.022$), muscle component content – by 1.43 % ($t=3.92$; $p=0.000$), relative maximum oxygen consumption – by 3.67 % ($t=2.30$; $p=0.028$), technical and tactical preparation by the coefficient efficiency – by 4.92 % ($t=2.11$; $p=0.043$).

During the ascertaining stage of the experiment statistically reliable positive shifts took place in the results of throwing a stuffed ball with two hands from behind the head on average by 3.11 % ($t=2.29$; $p=0.029$) and the muscle component content in the body of female athletes – by 0.84 % ($t=2.90$; $p=0.007$).

The obtained results confirm the effectiveness of building structural formations of the training process for the qualified volleyball players within the preparatory period of the annual training cycle on the basis of programming.

Discussion

The generalization of the results of previous studies indicates the prospects of programming the training process of athletes as an alternative to traditional planning, due to the need to regulate the components of the load to optimize

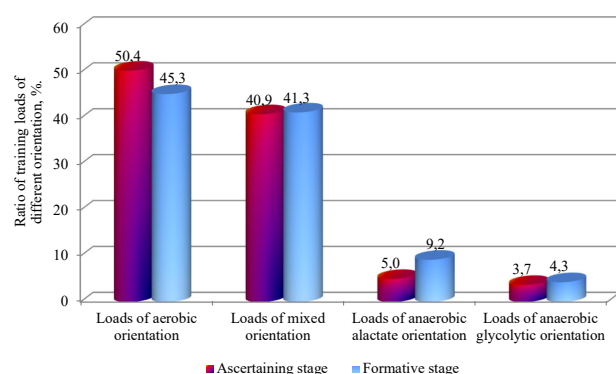


Fig. 4. The ratio of loads of different orientation of qualified female volleyball players in the preparatory period at the ascertaining and formative stages of the experiment, %

Table 4. Indicators of physical, functional, technical and tactical preparedness of qualified female volleyball players at the beginning of the ascertaining (AS, n=16) and formative (FS, n=16) stages of the pedagogical experiment

Sl. No	Research indicators	Statistical indicators					
		AS		FS		t	p
		M	SD	M	SD		
1	A standing high jump, cm	42.50	3.347	42.75	3.022	0.22	0.826
2	Throwing a stuffed ball with two hands from behind the head, m	7.40	0.306	7.44	0.364	0.35	0.731
3	Shuttle run 30 m (9-3-6-3-9 m), s	9.12	0.313	9.13	0.340	0.10	0.919
4	Run "herringbone" 92 m, s	27.39	0.489	27.37	0.461	0.15	0.812
5	Fat component content, %	24.31	1.494	24.09	1.757	0.37	0.714
6	Muscle component content, %	29.25	0.910	29.60	1.013	1.03	0.312
7	VO ₂ max, ml/min/kg	45.16	2.375	45.27	2.148	0.15	0.885
8	Efficiency coefficient, conventional units	0.62	0.031	0.61	0.032	0.45	0.656

Table 5. Changes in indicators of physical, functional, technical and tactical preparation of qualified female volleyball players at the stages of the ascertaining (AS, n = 16) and formative (FS, n = 16) pedagogical experiment during the preparatory period

Sl. No			Research indicators		Stage of the experiment	Statistical indicators						
						In the beginning		At the end		ΔM	t	p
1	A standing high jump, cm	AS	42.50	3.347	43.63	3.202	1.13	0.97	0.339			
		FS	42.75	3.022	44.94	2.489	2.19	2.24*	0.033			
2	Throwing a stuffed ball with two hands from behind the head, m	AS	7.40	0.306	7.63	0.274	0.23	2.29*	0.029			
		FS	7.44	0.364	7.75	0.298	0.31	2.63*	0.013			
3	Shuttle run 30 m (9-3-6-3-9 m), s	AS	9.12	0.313	8.98	0.318	-0.14	1.25	0.221			
		FS	9.13	0.340	8.96	0.301	-0.17	1.57	0.127			
4	Run “herringbone” 92 m, s	AS	27.39	0.489	27.12	0.451	-0.27	1.62	0.355			
		FS	27.37	0.461	26.85	0.407	-0.52	3.39*	0.034			
5	Fat component content, %	AS	24.31	1.494	23.72	1.432	-0.59	1.14	0.142			
		FS	24.09	1.757	22.65	1.618	-1.44	2.42*	0.022			
6	Muscle component content, %	AS	29.25	0.910	30.09	0.724	0.84	2.90**	0.007			
		FS	29.60	1.013	31.03	1.043	1.43	3.92**	0.000			
7	VO ₂ max, ml/min/kg	AS	45.16	2.375	45.53	2.304	0.37	0.45	0.658			
		FS	45.27	2.148	46.93	1.909	1.65	2.30*	0.028			
8	Efficiency coefficient, conventional units	AS	0.62	0.031	0.63	0.028	0.01	1.01	0.322			
		FS	0.61	0.032	0.64	0.039	0.03	2.11*	0.043			

Notes: * – the difference in results is statistically reliable at the level of $p < 0.050$; ** – the difference in results is statistically reliable at the level of $p < 0.010$

training effects and the directed formation of training effects (Stasyuk et al, 2021; Hidayah et al, 2024; Shynkaruk et al, 2025). In contrast to previous studies (Irvan et al, 2024; Muriyedath et al, 2025; Narayanan et al, 2025), which were devoted to the programming of individual aspects of training athletes in team game sports, in our work we reflected the use of a comprehensive system-structural approach to programming, which involves the subordination of programs of smaller structural formations of the training process to larger ones. This approach has been tested in the training

process of athletes in track and field all-around (Adamchuk et al, 2022, 2023), field hockey (Kostiukevych et al, 2024), football (Shchepotina, Kostiukevych, Asauliuk et al, 2021) and in the context of our study has confirmed its effectiveness in the practice of preparing qualified volleyball players.

In the course of the conducted research, the data of the existing scientific work (Leibo et al, 2021; Lima et al, 2024; Winther et al, 2024) on the volume, value, intensity, and ratio of loads in the training process of athletes were supplemented and expanded. In particular, according to

Adamchuk et al (2021), reducing the volume of training loads and increasing their intensity made it possible to reach the peak of sports form and to cause additional reserves in the body of athletes. It is especially actual in the context of implementation during the preparatory period of tasks of providing of optimal readiness of the researched volleyball players to loads of the long competitive period. Thus, we consider it expedient to reduce the volume of training loads and increase their intensity at the formative stage of the experiment, in comparison with the ascertaining one.

The training process of qualified volleyball players in the preparatory period at the formative stage of the experiment, in comparison with the ascertaining one, acquired a more pronounced specialized character, which was manifested in a decrease in the share of non-specific (general preparatory) means at the expense of an increase in specific, such as special preparatory and competitive exercises. Such an approach is more typical for the training of qualified athletes, which is consistent with the opinion of Platonov (2018) about the need to increase the specialization of the content of the training process with the growth of athletes' qualifications. In particular, the increase of the share of special preparatory exercises in a complex with the increase of the share of loads of anaerobic alactate and anaerobic glycolytic orientation at the formative stage of the experiment promoted the significant improvement of the display of high-speed and power abilities and speed endurance in interrelation with agility by volleyball players. The increase in the share of competitive exercises contributed to the improvement of the athletes' game practice, which is important for the establishment of group and team interactions (Shlonska, Borysova, & Yakusheva, 2024; Sobol et al, 2024). This, in our opinion, also manifested itself in a significant increase in the technical and tactical preparedness of qualified volleyball players.

The results of the measurements confirmed the expediency of using physical preparedness tests (Kostiukevych et al, 2019; Kozina, Polishchuk, & Polishchuk, 2023), as well as morphofunctional indicators (Shchepotina, Kostiukevych, Drachuk et al, 2021; Bezmylov et al, 2022; Kenney, Wilmore, & Costill, 2022) as criteria for the effectiveness of building training process of female athletes. The existing scientific heritage (Kozina, Polishchuk, & Polishchuk, 2023; Sieroń, Stachoń, & Pietraszewska, 2023; Shlonska, Borysova, & Yakusheva, 2024) was also supplemented with data on the dynamics of indicators of physical, functional, technical and tactical preparedness of qualified volleyball players during the preparatory period.

As for the dynamics of volleyball players' results during the ascertaining stage of the experiment, we note that a statistically significant improvement was found in indicators of throwing a stuffed ball with two hands from behind the head by 3.11 % ($t = 2.29$; $p = 0.129$), which characterizes the manifestation of high-speed and power abilities, and the content of the muscular component in the body of female athletes on average by 0.84 % ($t = 2.90$; $p = 0.007$). This, in our opinion, is due to the specifics of the game activity in volleyball associated with the performance of a large number of jumping and hitting movements, which contributes to the development of high-speed and power abilities and an increase in muscle mass (Shchepotina, Kostiukevych, Drachuk et al, 2021; Shlonska, Borysova, & Yakusheva, 2024).

The absence of statistically significant improvement in indicators of shuttle run of 30 m ($t = 1.57$; $p = 0.127$) in the

researched volleyball players during the formative stage of the pedagogical experiment we connect with the influence on this result of the display of high-speed abilities which are difficult to improve in adulthood (Bompa & Buzzichelli, 2018; Platonov, 2018; Kostiukevych et al, 2021). At the same time, we note the positive dynamics of agility in relation to speed in the indicator of shuttle run of 30 m. As for other results the statistically significant improvement of indicators of physical, functional, technical and tactical preparedness of qualified volleyball players during the formative stage of the experiment is noted, and it allows to recommend the offered program of the preparatory period for practical application in the training process of female athletes.

Taking into account that the opinion about the effectiveness of the use of programming in the training process of sportsmen (Guo et al, 2023; Ihsan et al, 2025) has been confirmed in our research, we consider it expedient to continue future searches in the direction of development of programs of competitive and transition periods of qualified volleyball players, and also to study the prospects of programming of stages of long-term improvement in team game sports.

Conclusions

1. Programming of the training process at the present stage is a more progressive form of planning, as it allows to carry out targeted managerial influences on the formation of training effects due to the regulation of components of the training load.

2. The program of the training process of qualified female volleyball players in the preparatory period was developed, which included four components: characteristic of training loads (volume 5400 min, total coefficient of load – 39742 points, average intensity coefficient – 7.4 points/min), structure of training loads (distribution of means: general preparatory exercises – 40.3 %, special preparatory exercises – 8.3 %, introductory exercises – 35.5 %, competitive exercises – 16.1 %; distribution of differently directed loads: loads of aerobic orientation – 45.3 %, mixed aerobic-anaerobic orientation – 41.3 %, anaerobic alactate orientation – 9.2 %, anaerobic glycolytic orientation – 4.3 %), quantitative indicators (the number of training sessions: non-specialized – 14, comprehensive – 28, specialized – 17; the number of games: training – 11, control – 5), criteria of efficiency of the training process (model indicators of physical functional, technical and tactical preparedness).

3. The structure of the program of the preparatory period consisted of the programs of the retractable mesocycle (included programs of two retractable microcycles), the basic developmental mesocycle (consisted of programs of two hitting and one restorative microcycle), the control and preparatory mesocycle (included programs of the ordinary, hitting and restorative microcycles), the pre-competitive mesocycle (consisted of programs of two introductory and one restorative microcycle). In accordance with the system-structural approach, the programs of microcycles made up the programs of training sessions, the structure of which was made up of the programs of training tasks.

4. The construction of the training process of qualified female volleyball players within the preparatory period on the basis of programming promoted statistically reliable ($p < 0.050$) improvement of indicators of physical fitness in the limits of 1.90-5.12 %, indicators of functional fitness in the

limits of 1.43-1.65 %, indicator of technical and tactical fitness – by 4.92 %. The obtained results confirm the effectiveness of the developed program of the preparatory period of qualified volleyball players and allow to recommend it for practical application in the training process of volleyball teams.

Conflict of Interest

The authors declare that there is no conflict of interest.

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Програмування тренувального процесу кваліфікованих волейболісток у підготовчому періоді річного циклу підготовки

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 11 с., 5 табл., 4 рис., 36 джерел.

Мета дослідження – експериментально обґрунтувати ефективність побудови структурних утворень тренувального процесу кваліфікованих волейболісток у межах підготовчого періоду річного циклу підготовки на основі програмування.

Матеріал і методи. В експерименті взяли участь кваліфіковані волейболістки І розряду студентської команди ($n=16$), середній вік яких становив 19.56 ± 0.81 років. Дослідження проводилося впродовж 2023-2024 рр. і включало два етапи послідовного педагогічного експерименту – констатувальний і формувальний. Формувальний експеримент передбачав розробку й експериментальне обґрунтування ефективності впровадження взаємопов'язаних програм структурних утворень тренувального процесу кваліфікованих волейболісток у межах підготовчого періоду річного макроциклу (програми періоду, мезо- і мікроциклів, тренувальних занять і їх частин – тренувальних завдань). Критеріями ефективності виступали показники фізичної підготовленості (стрибок у висоту з місця, кидок набивного м'яча масою 1 кг двома руками з-за голови на дальність, човниковий біг 30 м за схемою 9-3-6-3-9 м, біг «ялинкою» 92 м), функціональної підготовленості (вміст жиrowого та м'язового компонентів у тілі, відносне максимальне споживання кисню), техніко-тактичної підготовленості (коефіцієнт ефективності техніко-тактичних дій).

Результати. На формувальному етапі експерименту, порівняно з констатувальним, на 5.7 % (з 5725 до 5400 хв) було зменшено обсяг тренувальних навантажень, на 4.9 % (з 41804 до 39742 балів) знижено величину навантаження, на 1.4 % (з 7.3 до 7.4 бал/хв) підвищено інтенсивність навантажень; зменшено частку загальнопідготовчих (з 44.0 до 40.3 %) і підвідних (з 37.3 до 34.3 %) вправ, однак, за рахунок цього було збільшено частку спеціально-підготовчих (з 6.8 до 8.3 %) і змагальних (з 11.9 до 16.1 %) вправ; збільшено частку навантажень змішаної аеробно-анаеробної (з 40.9 до 41.3 %), анаеробної алактатної (з 5.0 до 9.2 %) й анаеробної гліколітичної (з 3.7 до 4.3 %) спрямованості за рахунок зменшення частки навантажень аеробної спрямованості (з 50.4 до 45.3 %).

Висновки. Побудова тренувального процесу кваліфікованих волейболісток у межах підготовчого періоду на основі програмування сприяла статистично достовірному ($p < 0.050$) покращенню показників фізичної підготовленості в межах 1.90-5.12 %, показників функціональної підготовленості в межах 1.43-1.65 %, показника техніко-тактичної підготовленості – на 4.92 %. Отримані результати підтверджують ефективність розробленої програми підготовчого періоду кваліфікованих волейболісток і дозволяють рекомендувати її до практичного застосування в тренувальному процесі волейбольних команд.

Ключові слова: програма, тренувальне завдання, мікроцикл, мезоцикл, тренувальні засоби, тренувальні навантаження.

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Understanding the Influence of Combined Teaching Styles on Football Passing Performance among PETE Freshmen Students

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Abstract

Background. The selection and effectiveness of teaching styles have been the focus of previous investigations. Therefore, further studies are needed to broaden the spectrum of teaching styles by exploring their combinations.

Objectives. This study aimed to investigate the influence of different teaching styles, specifically inclusion, guided discovery, and combined guided discovery-practice, on football passing performance among freshmen students enrolled in a Physical Education Teacher Education (PETE) program.

Materials and methods. The sample comprised 66 male first-year students enrolled in the Basic Football Skills course for the 2024/2025 academic year at the Physical Education Study Program, Universitas Cenderawasih, Indonesia. The participants were randomly assigned to one of inclusion, guided discovery, and combined guided discovery-practice groups, with each group consisting of 22 students. After confirming the necessary assumption, one-way ANOVA was conducted at a 0.05 confidence level, followed by a post hoc Tukey test.

Results. Each teaching style group showed an improvement in passing performance, confirming a significant influence of teaching style implementation on football passing performance among PETE freshmen students. One-way ANOVA revealed substantial differences among the groups ($p < 0.05$). After teaching style implementation, combined-GDP had the fastest passing performance time (67 seconds), compared to guided discovery (87 seconds) and inclusion (96 seconds). Furthermore, the results indicated that combined guided discovery-practice led to a better passing performance.

Conclusions. The findings of this study emphasized the effectiveness of combining teaching styles to enhance football passing performance among PETE freshmen students. Combined guided discovery-practice resulted in a better passing performance compared to guided discovery and inclusion styles. Therefore, combining teaching styles could help maximize the benefits and mitigate the limitations of individual teaching styles, typically leading to improved learning outcomes.

Keywords: combined teaching styles, inclusion, guided discovery, passing performance.

Introduction

Physical education (PE) is an educational process that uses physical activity to produce holistic individual well-being. PE contributes to the development of students' fundamental movement skills and physical competencies while simultaneously supporting social skills and behavioral growth (Bailey, 2006). Comprehensive studies have reviewed that PE improves student's physical activity levels and movement skills (Dudley et al., 2011). In addition, it serves as an effective tool for promoting lifelong physical activity,

contributing to good health and an active lifestyle (Ahmed & Al Salim, 2024).

In recent years, there has been growing concern about the declining levels of physical activity among young people. Physical activity levels in many societies are worryingly low across both adult and youth populations (Wintle, 2022). A study showed that managerial strategies should be applied to increase millennial participation in physical activity and sports (Sudharma, Asmawi, & Lubis, 2025). The key role of PE teachers in addressing young people's disengagement from physical activity has also been emphasized, consequently leading to lifelong benefits (Hein et al., 2012). Therefore, teachers employing more effective teaching styles can significantly improve students' engagement in physical

activity. The results confirmed the importance of teaching styles in PE classes (Rivas & Espada, 2021).

Mosston's Spectrum of teaching styles established a framework for possible relationships between teachers and students, emphasizing the central role of decision-making (Goldberger, Ashworth, & Byra, 2012). The spectrum includes eleven teaching styles, namely command, practice, reciprocal, self-check, inclusion, guided discovery, convergent discovery, divergent discovery, learner-designed individual program, learner-initiated, and self-teaching (Mosston & Ashworth, 2008). These styles are categorized based on the extent the teachers or students assume responsibility for the lesson. The five styles are classified as reproduction, where instruction focuses on replicating specific known skills and knowledge. The remaining six fall under production, where students are encouraged to discover new information, often unknown even to the teachers. This requires cognitive engagement in processes such as problem-solving, inventing, comparing, contrasting, and synthesizing (Chatoupis & Vegenas, 2018).

Experts have extensively studied the influence of teaching styles on learning outcomes, particularly in physical education and sports science, since the development of Mosston's Spectrum. Studies on teaching methodologies have been among the most analyzed topics in PE (Leo et al., 2023). Furthermore, the reproductive styles have proven effective in improving skill performance. An experimental study found that reciprocal style significantly improved basketball skills, such as jump shoot and dribbling (Alhayek, 2012). Similarly, inclusion style has improved volleyball skills, including finger passing, forearm passing, and underhand serving. Maria (2014) reported that direct method presented better results in developing movement skills among children aged 12 to 14. According to Dudley et al. (2011), command styles effectively increased children's physical activity levels and improved movement skill proficiency in primary schools. Inclusion style is specifically recommended for classes with participants who have special needs, such as dyslexia (Chatzipanteli, Konstantinidou, & Fotiadis, 2022).

Acting as a complement, production styles promote the development of motor coordination in relation to psychological factors. Morgan, Kingston, & Sproule (2005) emphasized that guided discovery fostered cognitive and affective responses compared to practice style. A recent study by Monacis et al. (2023) examining the effects of reproductive and productive teaching style interventions found that productive teaching styles significantly impacted self-perception and enjoyment of physical activity.

Few studies have begun to explore the combination of teaching styles. For instance, Cuellar-Moreno (2016) investigated the use of mixed reciprocal and guided discovery in teaching dance to primary school students. The results showed that the mixed style effectively improved technique and motor skills, comparable to command styles, while being more effective in strengthening students' attention capacity, satisfaction, and appropriate behavior. Similarly, Invernizzi et al. (2019) confirmed that a combination of teaching styles effectively improved fitness levels and motor competence, while also fostering enjoyment, physical activity levels, and students' perceptions of PE lessons in primary school children.

Based on discussions, this study aimed to compare the effectiveness of two teaching styles, namely inclusion

and guided discovery, lying at the threshold between reproduction and production styles, in improving motor skill abilities. To achieve this objective, an element of repetition was incorporated into the productive style by combining guided discovery with practice style to improve motor skill development more effectively.

Investigations on teaching styles in physical education have primarily focused on participants from PE classes. Moreover, studies involving teachers and prospective teachers remain limited. PETE programs are responsible for preparing future PE teachers (Davis, 2019). Recently, the program has faced numerous challenges, including mastering technology, foreign languages, diverse teaching skills, and professional development (Ward & van der Mars, 2020). Teachers also require psychological capital and social support to create a holistic PE teaching model (Jannah et al., 2024). Consequently, an experimental study was conducted on PETE students, who were prospective PE teachers. Mastery of basic sports movement skills is essential for prospective PE teachers. Therefore, the first year of PETE curricula generally introduced courseworks in Exercise and Sport. The Basic Football Skill course is one of the compulsory courses offered in the first semester at the Physical Education Study Program, Universitas Cenderawasih. One of its key learning outcomes is acquiring fundamental technical skills, including passing techniques. The objective of this study was to analyze the influence of different teaching styles, namely inclusion, guided discovery, and combined guided discovery-practice (combined-GDP), on football passing performance among PETE freshmen students at Universitas Cenderawasih, Indonesia. Based on discussions, the following study questions were proposed:

1. Does the implementation of different teaching styles have a significant influence on passing performance among PETE freshmen students?
2. Which teaching style can achieve a better passing performance among PETE freshmen students?

Materials and Methods

Study Participants

A quasi-experimental design was used in the Physical Education Study Program at Universitas Cenderawasih, Indonesia to achieve the objectives. A total of 66 male freshmen enrolled in the Basic Football Skills course during the first semester of the 2024/2025 academic year actively participated. In this study, all participants were randomly assigned to either inclusion, guided discovery, or combined guided discovery-practice group, with each consisting of 22 students. All participants provided informed consent, and the procedures received approval from the Health Research Ethics Committee of the Health Polytechnic of Jayapura (No. 168/KEPK-J/XII/2024).

Study Organization

Football passing performance was assessed at both the beginning and end of the experimental teaching unit using the Loughborough Soccer Passing Test (LSPT) developed by Ali et al. (2007). During the test, participants were required to pass toward a target board following specific instructions

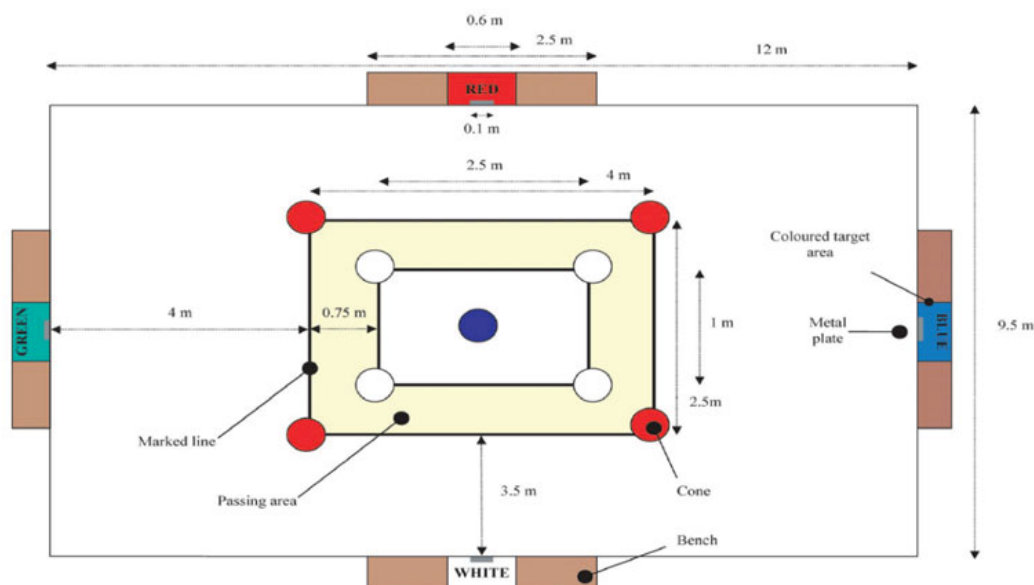


Fig. 1. Schematic representation of the LSPT; Copyright from Ali et al. (2007)

provided by Examiner 1, who was the only one aware of the predetermined passing sequence. Examiner 2 was responsible for recording penalty time points accumulated during the trials. Penalty time was assigned for the following errors: 5 s for missing the target completely or passing to the wrong target; 3 s for missing the color target area; 3 s for handling the ball; 2 s for passing the ball from outside the designated passing area; 2 s for the ball touching any cone; 1 s for each additional second besides the allocated 43 seconds to complete the test; and 1 s deducted from the penalty time when the ball hit the colour target. The final test score was calculated as the total time taken to complete the 16 passes, including any penalty time. A schematic representation of the LSPT is presented as follows.

A simple randomization procedure was applied to assign three classes into inclusion, guided-discovery, and combined guided discovery-practice (combined GDP) groups. Teaching units are described in Table 1.

Table 1. Teaching style descriptions

Inclusion	Teachers prepare a series of passing lessons, progressing from simple to complex levels. Students select a starting point from the available passing lessons and continue with the next level until all lessons are completed.
Guided Discovery	Teachers set learning targets for passing techniques and provide guidance through problem statements. Students think independently, make decisions, and execute passing techniques.
Combined GDP	Teachers set learning targets for passing techniques and provide guidance through problem statements. Students think independently, make decisions, and execute passing techniques. After students develop an understanding of passing, teachers provide direct guidance, followed by repetitive passing exercises to improve skills.

Statistical analysis

The hypotheses were tested using one-way ANOVA, with a confidence level of 0.05. Before conducting variance analysis, assumption tests, including Shapiro-Wilk normality and Levene's homogeneity tests, were performed. Moreover, a Turkey post hoc test was conducted for multiple comparisons. All statistical analyses were performed using SPSS version 25 (SPSS Inc., Chicago, Illinois, USA).

Results

Shapiro-Wilk normality test was conducted to determine whether the data followed a normal distribution before performing inferential statistical analysis. The significance value for all groups was greater than 0.05, confirming that the data were normally distributed. Furthermore, Levene's test resulted in $0.688 > 0.05$, confirming that the data were homogenous. These assumption tests validated the use of the data for hypothesis testing.

Before the study began, a preliminary LSPT was conducted to determine whether the groups were statistically different from one another. Since the study involved three different groups, one-way ANOVA was performed to assess the equivalence of students' passing skills before the intervention. The results, presented in Table 2, showed that the initial passing performance was similar across all groups before teaching process began ($p > .05$).

Table 2. One-Way ANOVA Analysis of Pre-test Passing Performance

	Sum of Squares	df	Mean square	F	p
Between Groups	1136.455	2	567.337	2.068	0.135
Within Groups	17306.818	63	274.711		
Total	18443.273	65			

A dependent t-test was conducted to evaluate changes in passing performance within each group after

Table 3. Comparison of Pretest-Post-test Mean in Passing Performance from Different Teaching Styles

Teaching Styles Group	Pre-Test	Post Test	Mean Difference	SD	SE	t	p
Inclusion	111.50	96.318	15.1818	9.7083	2.069	7.335	0.000
Guided discovery	102.50	87.64	14.864	11.618	2.477	6.001	0.000
Combined GDP	102.91	67.41	35.500	14.796	3.155	11.254	0.000

the implementation of teaching styles. Based on Table 3, the mean difference showed a decrease in LSPT total scores, confirming an improvement in football passing performance. The t-value and significance level confirmed a statistically significant difference in passing skills before and after teaching process.

Based on Table 4, another one-way ANOVA was conducted to compare passing performance among the groups after teaching style implementation. The results showed that passing performance significantly differed between the groups ($p < 0.05$).

Table 4. One-Way ANOVA Analysis of Post-test Passing Performance

	Sum of Squares	df	Mean square	F	p
Between Groups	9681.848	2	4840.924	25.630	0.000
Within Groups	11899.182	63	188.876		
Total	21581.030	65			

A post-hoc test was conducted to further investigate the differences between groups. This test was performed on the total post-test scores to determine the group with significant differences in passing performance. The results showed that each group differed significantly from the others ($p < 0.05$). Therefore, a post-hoc analysis was necessary to identify where the differences occurred. Tukey post-hoc test was used due to the balanced data (Lee & Lee, 2018).

Table 5. Pairwise comparison of the final passing performance in different teaching style groups

I (Teaching Styles)	J (Teaching Styles)	Mean Difference (I-J)	SE	p
Inclusion	Guided discovery	8.682*	3.488	.016
	Combined GDP	28.909*	3.488	.000
Guided discovery	Inclusion	-8.682*	3.488	.016
	Combined GDP	20.227*	3.488	.000
Combined GDP	Inclusion	-28.909*	3.488	.000
	Guided discovery	-20.227*	3.488	.000

* $p < 0.05$

Table 5 presents the pairwise comparisons of the final passing performance across different teaching style groups. The comparisons showed statistically significant differences ($p < 0.05$).

Discussion

This study aimed to investigate the influence of different teaching styles, namely inclusion, guided discovery, and

combined guided discovery-practice (combined-GDP), on football passing performance. Variance analysis of initial passing performance confirmed that all students had similar passing skills before teaching intervention. The pre-test passing performance, measured using LSPT, showed mean values of 111.50, 102.50, and 102.91 seconds for inclusion, guided discovery, and combined-GDP groups, respectively. Since LSPT performance was based on total test completion time, including penalties for errors, lower scores confirmed better performance.

Several studies have used LSPT to differentiate performance levels among players although explicit clustering analyses of LSPT scores are limited. For instance, a study on adolescent football players classified participants based on skill level, reporting elite players with an average completion time of approximately 40 seconds, sub-elite players at 58 seconds, and non-elite players at 67 seconds (Moal et al., 2013). Another study evaluating LSPT performance among beginner-level adolescent football players found that competitive players completed the test in approximately 62 seconds, while recreational players required around 72 seconds (McDermott, Burnett, & Robertson, 2015). A study on male college students reported an average LSPT completion time of 74 seconds, with times exceeding 80 seconds under fatigue conditions (Lyons, Al-Nakeeb, & Nevill, 2006). In the current study, pre-test LSPT scores showed poor passing performance when compared to both soccer players and university-level students from previous investigations. The results showed freshmen PETE students at Universitas Cenderawasih lacked basic football techniques upon entering physical education program. This corresponded to the learning outcomes of the Basic Football Skills course, aiming to equip students with basic football techniques, including passing skills.

Each group showed an increase in passing performance after implementing different teaching styles, as expressed by pretest-posttest t-values of 7.335, 6.001, and 11.254 for inclusion, guided discovery, and combined-GDP, respectively. The results addressed study question #1, confirming that teaching style implementation significantly influenced passing performance among PETE freshmen students. To address study question #2, Tukey post-hoc test showed that the three-teaching styles resulted in different performance outcomes. Combined-GDP showed a highly significant difference compared to both inclusion and guided discovery groups with a significance value equal to 0. Meanwhile, the difference between inclusion and guided discovery was $p = 0.016$. Although this value still confirmed a statistical difference, p-values between 0 and 0.05 reflected varying degrees of significance (Lee & Lee, 2018). Therefore, the answer to study question #2 was that combined-GDP produced the best passing performance, followed by guided discovery, and inclusion. Combined-GDP helped students achieve performance levels comparable to non-elite players

(approximately 67 seconds), while guided discovery achieved performance similar to typical university students (87 seconds). Despite significant improvements, students taught using an inclusive style performed at a lower level (> 90 seconds).

The significant improvement in inclusion group can be attributed to the physicality and cognitive involvement of students, in line with a study conducted on university students in the USA (Sanchez, Byra, & Wallhead, 2012). However, observations showed students in inclusion group tended to select easier and less challenging lesson sequences, in line with (Chatoupis & Emmanuel, 2003). This might explain why, despite significant post-test improvements, inclusion group's mean post-test score remained the lowest compared to the other groups.

Regarding the guided discovery teaching style, previous studies have also shown its effectiveness in improving kinetic satisfaction and performance (Mahmoud, 2018), as well as motor skills (Newell & Rovegno, 2021). The results corresponded with a report that guided discovery promoted cognitive and affective responses (Morgan, Kingston, & Sproule, 2005). Studies comparing guided discovery to traditional command teaching styles found that guided discovery produced superior skill retention (Khouri et al., 2020). Although guided discovery encouraged students to explore and find solutions independently, this style could present challenges for students with limited motor skills. According to Newell & Rovegno (2021), careful task design and teachers guidance are essential for ensuring the effectiveness of guided discovery, particularly for learners with varying skill levels. Moreover, recent studies reported that its effectiveness depended on learners' initial skill levels (Moreno-Murcia, De Paula-Borges, & Trinidad, 2024). Students with lower initial competence may require more structured guidance to fully benefit from guided discovery methods.

Finally, the faster passing performance time of combined-GDP compared to inclusion and discovery learning groups further supported the conclusion that teaching style was the most effective for improving passing performance among PETE freshmen students. This study emphasized how incorporating repetition elements could address the limitations of guided discovery, particularly for students with poor initial skills. The optimized results showed that by the end of the learning process, PETE freshmen students could reach performance level of non-elite players.

Conclusions

In conclusion, this study showed the combination of teaching styles was crucial for physical education teachers to improve student's learning achievements. Despite the wide teaching spectrum, combining different teaching styles could help balance the respective strengths and weaknesses. The results showed that while each teaching style contributed to improving performance, particularly in passing motor skills, a combination of teaching styles produced even more significant results. Combined-GDP specifically led to better passing performance outcomes compared to guided discovery and inclusion. Therefore, teachers should be well-versed in various teaching styles and understand how to effectively combine and adapt the styles to create new methods for supporting desired learning objectives.

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Conflict of Interest

The authors declare no conflicts of interest.

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Розуміння впливу комбінованих стилів викладання на результативність виконання пасів у футболі серед студентів-першокурсників програми підготовки вчителів фізичного виховання

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 7 с., 5 табл., 1 рис., 32 джерела.

Історія питання. Вибір та ефективність стилів викладання перебували у фокусі уваги попередніх досліджень. Тому необхідно провести подальші дослідження для розширення спектру стилів викладання шляхом вивчення їхніх комбінацій.

Мета дослідження. Це дослідження мало на меті вивчити вплив різних стилів викладання, зокрема, інклюзії, методики керованого відкриття та практики комбінованого керованого відкриття, на результативність виконання пасів у футболі серед студентів-першокурсників, які навчаються за програмою підготовки вчителів фізичного виховання (ПВФВ).

Матеріали та методи. Вибірка складалася з 66 студентів-першокурсників чоловічої статі, зарахованих на курс із засвоєння базових футбольних навичок у 2024/2025 академічному році за навчальною програмою «Фізичне виховання» в університеті Чендеравасі, Індонезія. Учасників було розподілено за методом рандомізації до груп інклюзії, керованого відкриття та практики комбінованого керованого відкриття, кожна з яких налічувала 22 студенти. Після підтвердження необхідних умов було проведено однофакторний дисперсійний аналіз з рівнем достовірності 0,05, після чого застосовано post hoc тест Тьюкі.

Результати. Кожна група, що навчалася за певним стилем викладання, продемонструвала покращення показників виконання пасів, що підтверджує значний вплив застосування стилю викладання на результативність передач у футболі серед студентів-першокурсників програми ПВФВ. Однофакторний дисперсійний аналіз виявив суттєві відмінності між групами ($p < 0,05$). Після впровадження стилю викладання встановлено, що група, в якій застосовувалася практика комбінованого керованого відкриття мала найшвидший показник часу щодо результативності виконання пасів (67 секунд), порівнюючи з групами керованого відкриття (87 секунд) та інклюзії (96 секунд). Крім того, результати показали, що впровадження практики комбінованого керованого відкриття забезпечило поліпшення результативності виконання пасів.

Висновки. Результати цього дослідження підкреслили ефективність поєднання стилів викладання з метою підвищення результативності виконання передач у футболі серед студентів-першокурсників програми ПВФВ. Застосування практики комбінованого керованого відкриття призвело до покращення результативності виконання пасів, порівнюючи зі стилями керованого відкриття та інклюзії. Таким чином, поєднання стилів викладання сприятиме максимізації переваг і зменшенню обмежень щодо впровадження окремих стилів викладання, що, як правило, призводить до поліпшення результатів навчання.

Ключові слова: комбіновані стилі викладання, інклюзія, кероване відкриття, результативність виконання пасів.

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Biomechanical Kinetic Chain Analysis of Service Motion for Speed Ball Prediction Through SBM-03 App Development

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Abstract

Background. The kinetic chain of the serve stroke is a coordinated activation of body segments (legs, torso, shoulders, arms, and hands) that begins with the ground reaction force against the legs on the ground and ends with racket acceleration through the ball. The objective of this study is to place the end segment, hand, and racket in an optimal position at an optimal speed to "make the ball travel" as best as possible. The efficient use of the kinetic chain segment creates a much greater racket velocity than its parts. On the contrary, a broken kinetic chain makes the ball speed less optimal and can even lead to injury. However, the reality is that the kinetic chain movement and ball speed rate cannot be seen simply using the observation method. Thus, a specific technology is needed to diagnose it.

Objectives. This study aimed to develop a digitalized system of software to help measure the ball speed rate based on the kinetic chain of the serve stroke.

Materials and methods. The research method employed in this study was research and development (R&D). The data were collected by recording videos of 10 professional athletes' serve strokes. These videos were then analyzed using software to check their movement angles.

Results. The findings showed that the average angles were as follows: elbow = 120.490, shoulder = 166.010, hip = 165.330, knee = 165.880, ankle = 173.790, and ball speed = 24.33 m/s.

Conclusions. Some conclusions were drawn from this study. First, the more significant portion of the kinetic energy of force produced in a serve was developed on the legs and body torso. Every segment generated force and acted as a stabilizer structure for the next segment's activity. Fifty-one percent of kinetic energy and 54 up to 60 percent of the total force were produced this way. Second, the kinetic chain was oriented towards changing the linear or straight-line momentum into an angular or rotational momentum around the stable pillar leg. Third, each segment had tilting or stabilization and acceleration phases. Fourth, a big and fast movement was needed in the joints, especially the shoulders. Finally, the broken segment or kinetic chain reduced the ultimate force or energy available to travel the ball and put enormous pressure on the surrounding segments. A decrease in kinetic energy by 10 percent from the hip or body to the shoulder while doing the serve required an increase in the shoulder's rotation by 14 percent or an increase in the shoulder's mass by 22 percent to create the same kinetic energy on the hands and racket. There were some reasons for the broken kinetic chain, but the most general ones included muscle weakness, inflexibility, joint injury, and poor stroke mechanics.

Keywords: kinetic chain, technology, serve, tennis.

Introduction

In tennis, every game begins with a serve (Fett et al., 2020). An effective, hard and accurate serve is what all athletes dream of. The main keys to a successful serve are speed,

rotation and placement (Martin, 2018). The serve speed is one of a determining factor of tennis performance (Colomar et al., 2022; Fett et al., 2020). An athlete's ability to get the first serve ball speed is an important element of a successful game (Maquirriain et al., 2016) and a major advantage for a player (Martínez-Gallego et al., 2020). A good first serve makes the opponent feel pressured and less optimal to return it, allowing a server to have greater chance for points than their opponents. A good first serve enables the player to get

rally points in a short time with a percentage of points won by 72-81% (Hizan et al., 2011). In addition, a successful first serve has developed into a powerful tool for gaining immediate points or taking instant initiative in a rally (Keller et al., 2021). Based on the research data in the field, male tennis players have 65% (Australia Open and France Open) and 70% (Wimbledon) change of winning if the first serve can be maintained during the match (Meffert et al., 2018).

A kinetic chain begins from the legs, develops to the hip, body torso, upper arms, lower arms, and eventually to the hands and the racket (Fu et al., 2018; Terré et al., 2024). The right kinetic chain (movement execution, technical skills, kinetic chain coordination) is needed by professional players (Fett et al., 2021). In a kinetic chain, the hip is the connector between the legs and the body, and the abdomen is the connector between pelvic girdle and shoulder girdle. The pelvis and body torso are a vital connector in a set of actions while doing the serve.

Interestingly, from the biomechanic perspective, a serve is characterized by a bottle-opening movement, after the ball is thrown, the serving arm moves behind the body and the vertebral column is laterally bent and hyperextended with the lower body fully loaded. The racket and arm acceleration when serving before the impact point is accompanied by counter-rotational acceleration of the lumbar spine, from hyperextension to flexion from right rotation to left rotation (Kovacs & Ellenbecker, 2011). When starting the service, the front foot is placed to the right net post and the back foot is parallel to the baseline. The front heel and the back toes are aligned to create stability (Fett et al., 2021).

Considering the problems above, it is important to conduct research analyzing the kinetic chain (Liang et al., 2023) in producing a serve stroke that has high speed and accuracy. Nevertheless, a service is the most difficult technique to master compared to other techniques as it needs a complex combination and coordination of joints and leg movements required to transfer force from the bottom to the racket head known as the kinetic chain (Kovacs & Ellenbecker, 2011). Hence, a precise and in-depth investigation on kinetic chain is needed to generate an optimal stroke. It will surely be not an easy task if a coach analyzes this kinetic chain and predict the resulting ball speed when they only rely on observation without involving any science and technology in it.

Most studies on kinetic chain start from the lower limbs up and the body torso joint movements (Wagner et al., 2014), racket and ball kinematics (Whiteside et al., 2013), gender, age, performance, and injury-related kinematics (Campbell, 2013), the effects of flat or slice serves (Carboch et al., 2018), and body and ball kinematics in deuce and Ad situations (Fett et al., 2021). However, to the best of researchers' knowledge, no studies have been conducted on the predicted correlation between the kinetic chain of service stroke and the produced ball speed rate. The analysis was done through the kinetic chain at the time of ball impact (Eaton et al., 2013). In each phase (Wang et al., 2021), the kinetic chain angle of the athlete's biomechanical movements during service will be read, including: elbow, shoulder, hip, knee and ankle (Fleisig et al., 2003; Parunchaya et al., 2025). The analysis was carried out using a readily accessible and operable Android-based application to make it easier for coaches to analyze the athletes' movement problems. This application system works by reading one athlete's movement into several detailed series of movements taken from live

video recordings or replays, then connected to an Android mobile phone or computer that has the application installed. The application was also designed to automatically read the ball speed as the athlete did the serve (Zhao et al., 2019).

Materials and Methods

Participants of Study

Research and Development (R&D) was used for the current research with quantitative data. The research population consisted of 5 male 12th-grade student national athletes of Central Java and 5 male athletes from Tennis Club at UNNES. As every individual in the population participated in the research, the sample reached saturation, with the only criterion being male athletes, resulting in a total of 10 athletes as the sample.

Organization of Study

For this research with experimental design, the data were collected by distributing questionnaire to experts to allow them to determine whether the instrument was valid or not. The test was done in three repetitions. A ball launcher and a camcorder were used in the test. In addition, the camcorder was integrated to an Android mobile phone to record the video. The product developed in this research was SBM-03 application. Its design allowed the researcher to predict the speed of forehand stroke as shown by the angle of biomechanic movement when the ball impact occurred.

This product observed the biomechanic movement of some body parts involved in the movement such as hips, ankles, shoulders, knees, and elbows at the moment of ball contact. Additionally, the system was capable of automatically computing the angle. Furthermore, it collected data from pictures of tennis players employing an image acquisition circuit of Modbus IoT (Internet of Things) sensor. The product utilized the principle known as human pose detection to measure the player's movement angle, using 32 points on the body, while tracking the speed of the ball. Once the numbers regarding angles of movement and ball speed were obtained, they were then saved in Excel as the deliverables.

The procedures for developing the research involved: 1) analyzing the product, 2) developing the software and

Table 1. Main Components of Software

Software Name	Icon	Function
Python 3		A programming language used as communication to make it possible to track objects. In this case the objects were human beings and a tennis ball.
VS Code		To edit the programming language.
Irun		To link the webcam to the computer via a Wi-Fi connection.

Table 2. Main Components of Hardware

Hardware Name	Figure	Function
Webcam		Used to record videos real-time at the predetermined corner of the court.
Tripod		Serving to support the webcam in recording the video.
Surveyor's tape		To determine the angle from which the video was taken and the dimensions of the court.

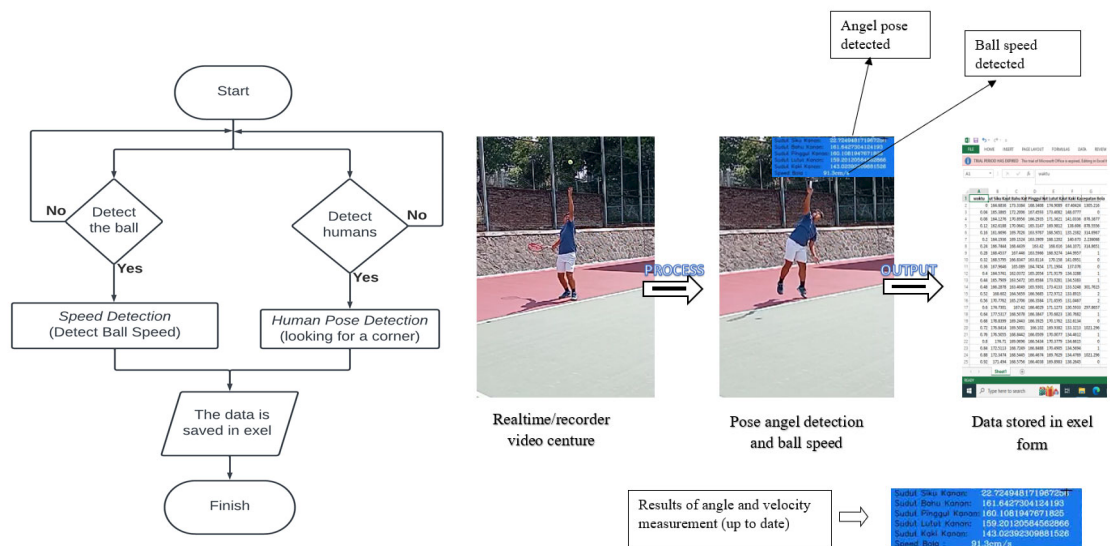
product prototypes, 3) having the product assessed by experts, 4) testing the product, and 5) revising the product.

The research started with an analysis of the components to be used. The product's output would be data on ball speed and poses of the players while the game was ongoing. The data needed were spatial ones in RGB format the frame of which contained the players and the ball. Below is the list of main components used.

The movement angle of players was detected based on the so-called human pose detection principle, that had 32 points on the body and the speed of the ball was also tracked. The deliverables of this athlete movement and ball speed detection were saved in Excel. The flowchart of how this system worked is as follows:

Statistical Analysis

Since descriptive, inferential analysis with Two-Way ANOVA classification was employed in this study, the following formula was used.

**Fig. 1.** Workflow of System**Table 3.** Average ball impact of athletes' first serve

No	Player's	Elbows	Shoulders	Hips	Knees	Ankle	Ball Speed, m/s
1	A	108.53	163.83	172.07	179.98	169.32	26.8
2	B	33.85	151.38	161.34	176.89	166.19	24.8
3	C	95.19	157.27	165.08	175.69	174.48	24.67
4	D	155.08	170.1	165.64	179.64	178.56	24.54
5	E	176.29	174.09	162.73	162.6	174.3	24.22
6	F	159.55	164.71	162.48	174.7	177.8	24
7	G	152.58	168.01	166.09	168.42	164.75	23.75
8	H	62.84	178.84	177.6	168.8	168.85	23.54
9	I	111.16	173.82	164.93	176.64	169.3	23.52
10	J	149.84	158.08	160.81	174.61	173.78	23.47
Avarage		120.491	166.013	165.877	173.797	171.733	24.331
SD		44.076269	8.193724489	4.950935366	5.237692335	4.486457511	0.946503566

$$F = \frac{Rka}{Rkd} > F_{k-1; n-k} \text{ or Sig. } (P_value)$$

Where:

$$JKa = nS X^2 - \frac{\sum X^2}{k}$$

$$JKd = JKsmk$$

$$JKT = Jka + JKd$$

$$df JKa = k-1$$

$$df JKd = N-k$$

To make sure that the results were accurate, this research used SPSS version 25. Figure 1 shows the sample tested in the trial. Furthermore, it presents how the system product functions.

Results

This study on serve stroke was conducted at tennis courts of GOR Jati Diri, Semarang Municipality, on 16 October 2024. In the first serve stroke trial with 10 athletes in 10 repetitions respectively, and after being calculated on average, the following results were obtained:

Table 3 shows that when the ball made contact, the angles, on average, were 171.730 for ankles, 173.790 for knees, 165.880 for hips, 166.010 for shoulders, and 120.490 for elbows with the ball speed being 24.33 m/s at 0.95 ball speed standard deviation. From these findings, it could be said that the software could measure the angles of kinetic chain and the speed of the ball in an accurate manner. Upon analyzing as many as 206 frames, every stroke was computed by the system. All that the researchers needed to do was deciding on the point to make the ball impact optimal and analyzing every movement as per the movement mechanics.

The body parts acted as a system of chain links where energy (or force) was produced by one of the chain links (or body parts), transferred in sequence to the next chain link. Its application in the serve was as follows:

Discussion

This research aimed at analyzing the kinetic chain of serve stroke using a digitalization technology. The main problem was how to measure the angle of joint kinetic chain and racket speed to produce an optimal ball speed. In general, the angles of joint kinetic chain and racket speed could be measured well by the product.

In a serve, there were a number of similarities that were prerequisites for the stroke to be executed most efficiently and effectively. The first one was stable foundation. The legs should be parallel, open, and positioned sideways to allow the knees to do some flexion and develop the lower and upper body rotational momentum. Greater knee flexion during preparation contributes to racquet speed (Hornestam et al., 2021). The second one was simultaneous movement of both arms. The throwing arm followed the line of rotation of the body when the hitting arm was in the cocked position (racket face closed). This closed racket position was best achieved with a proper (continental) serve grip. As both of their arms working together in such a way, the player would be better able to achieve the desired trunk and shoulder rotation. The third one was the hitting phase. This phase began when the hitting hips, body and shoulder rotated. This was followed by the deceleration of the right hip (blocker), which allowed the transfer of energy to the shoulder and arm. The shoulder internal rotation (front elbow) affected the racket's fall continuity and the elbow's forward acceleration. The fourth one was extension movement. The racket started to rise quickly on the edge. This allowed for optimal shoulder internal rotation and forearm pronation. The fifth one was contact. At this point, the full extension of the hitting side was shown. The forearm pronation and the wrist outward rotation continued until impact. When contact occurred, the vertical racket speed was positively related to the hip rotation (Vacek et al., 2023). The ball speed was also affected by whether the head angle was opened or closed (Vaverka et al., 2018). To optimize the high racket head speed, flexibility of hands and upper arms as well as trunk and shoulder internal rotations were needed (Delgado-Garcia et al., 2019). Some studies reported that when the contact occurred, the elbow was not fully extended (Fett et al., 2021) since it would reduce the pathological risk such as loose body formation. Just like the elbow, when the serve contacted, the configuration of the shoulder joint could cause pain and pathology (Gillet et al., 2017). The sixth similarity was deceleration. After a powerful ball-hitting motion and a long follow-through, the player regained their balance.

To produce kinetic chain force efficiently for a serve, four common points in the kinetic chain sequence were needed. First, the leg/hip segment needed some degree of knee flexion when cocking. Knee extension from flexion then provided upward linear momentum, transferring the

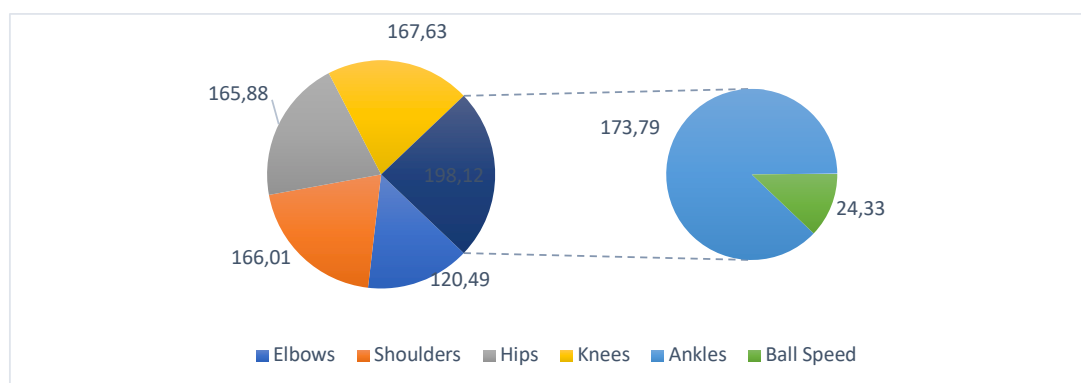


Fig. 2. Mean Kinetic Chain of First Serve Impact

Table 4. Working System of Serve Kinetic Chain

Body Part	Description
Leg drive	Increases velocity of hip
Trunk and shoulders rotation	Increases shoulders velocity
Upper arm	Increases elbow velocity
Elevation	Aligns the racket for impact and Increases wrist velocity
Forearm extension and pronation	Increases racket speed
Hand flexion	The second part of the link in the chain is the use of the hips.
Hip rotation	The Advanced player will transfer the power generated by the knees to the trunk through the hips. Hip rotation occurs after the knees bend, and then straighten. Such an action upwards drivers the shoulder up and out which forces the racket further down the back of the server. This phenomenon is called displacement and requires excellent co-ordination.
Trunk rotation	Once the force has been transferred from the ground, through the legs to the hips, and the hips achieve maximum rotation speed, then trunk is rotated. Most good servers have considerable trunk rotation. Note that as the trunk rotates the left arm is tucked in front of and across the body. This arm action acts to decelerate the trunk rotation thus allowing the arm to accelerate out towards the target.
Rotation of the arm about the shoulder (power loop)	Following the trunk rotation, the next link in the system is the rotation of the arm about the shoulders. When the arm is at the bottom of the backswing behind the back, it is externally rotated at the shoulder. On the upward or forward swing, the upper arm internally rotates at a very high speed.
Elbow Extention – Forearm pronation	The next part of the link involves the elbow in two ways: The elbow extends from position when the racket is behind the back (in the power loop), and Pronation (turning outward) of the forearm and hand around the elbow occurs The speed of these two actions is very high and care should be taken to avoid injury.
Wrist flexion	In the backswing (behind the back) and early forward swing the wrist is hyperextended (the hand bends back at the wrist). As the racket head accelerates towards the impact points, the hand flexes at the wrist until, at impact, it is relatively straight compared to the forearm, and then racket head continues at high speed so that the wrist flexes. The wrist action from a hyperextended position, through to a straight (at impact) and then flexed position (after impact), is the final stage in the chain of links which produces a powerful serve.
Follow through and landing foot	The completion of the weight transfer forward moves the body into the court. The face of the racket does an outward rotation that reduces the strain of the shoulder joint. The racket moves across the body and decelerates. The body starts to recover its balance for the next shot.

ground reaction forces to the body (Fett et al., 2021). The leg in the back provided most of the upward and forward thrust, while the front leg provided a stable pole to allow for rotational momentum. This created a “pushing” motion from the ground to the racket. Second, the body and scapula had to rotate and retract, to allow for a shoulder/arm position when cocking. This served to store a full tank of energy. A stable body position allowed a quick acceleration to the ball. Third, the shoulder needed to rotate externally and abducted horizontally to reach the cock, and rotated internally while accelerating. The shoulder internal rotation from the cocked position to acceleration was the single most important biomechanical variable in the kinetic chain of a serve, had the highest speed, occurred the closest to the ball impact, and allowed maximum acceleration through the ball (Moreno-Pérez et al., 2019).

The flexibility and internal rotation of the upper shoulder during the rotation phase played an important role in racket (Antrenmanların, 2020; Martin et al., 2014; Söğüt, 2017). The acceleration phase began with maximum lateral rotation

of the shoulder at the end of the cocking phase (Zappala et al., 2017). Finally, the forearm pronated to accelerate the racket through the hitting zone. This movement was combined with internal rotation of the shoulder (Whiteside et al., 2013).

The capacity to increase the absolute ball speed started with lower body mechanics and followed by that of the upper body (Butler et al., 2020; Gallo-Salazar et al., 2017). It is important for angle and shoulder to be tilted and accompanied by knee flexion (Antúnez et al., 2012). The knee extension during trunk/scapular rotation acceleration reached the “full tank of energy” while tilting external shoulder rotation (backward) and internal rotation (forward). (Zhang & Chen, 2024) suggested that internal rotation of the humerus and pronation of the forearm contributed to the effectiveness of tennis strokes. The same applied to the forearm pronation (outward rotation of the wrist) (Palmer et al., 2018).

The advantages of this research product included its ease and practicality for use as well as its effectiveness to measure the kinetic chain and the resulting ball speed. Nevertheless,

this product still had its limitations, such the different correlation between measurement angle of kinetic chain and the resulting ball speed among players. It was possible that this was a result of some factors, including heights, weights, arm length and angel position when the video was taken.

The previous studies showed that arm length and height affected the serve speed (Ma et al., 2024). The correlation of first serve between anthropometry and speed: height, upper arm length, arm circumference and Body Mass Index BMI (Moreno-Pérez et al., 2019). A significant correlation occurred between serve speed and BMI, and this was associated with the potential increased muscle mass on power (Vaverka and Cernosek, 2013).

The challenge to deal with was to find a way to increase the accuracy degree of ball speed and the joint kinetic chain angle despite the athletes' different anatomical structure. Regardless of this challenge, this research had its own added value thanks to the ease of collecting its data, where only smartphone or Android mobile phone was sufficient to collect the data and analyze the kinetic chain and ball speed while performing the serve stroke.

Conclusions

The serve stroke technique could be assessed and measured using this tool. It is suggested for coaches and athletes to use this tool to consider the effectiveness of kinetic chain of serve stroke technique to generate an optimal ball speed. When differences in movement are spotted, this software would be able to identify what goes wrong in the movement, enabling coaches to apply a corrective strategy in the following practice session. It is recommended for future research to consider other variables such as height, weight, arm length and to use camera from multiple angles to make the product analysis more precise and accurate.

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Conflict of Interest

All authors have declared that they have no conflict of interests.

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Біомеханічний аналіз кінетичного ланцюга руху подачі щодо прогнозування швидкості польоту м'яча шляхом розроблення додатку SBM-03

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 8 с., 4 табл., 2 рис., 39 джерел.

Історія питання. Кінетичний ланцюг удару під час виконання подачі представляє собою скоординовану активацію сегментів тіла (ніг, тулуба, плечей, рук і кистей), яка починається з моменту сили реакції опори, що виникає у відповідь на тиск ногою на опору і завершується прискоренням удару ракеткою по м'ячу. Мета цього дослідження полягає в позиціонуванні кінцевого сегмента, кисті руки та ракетки в оптимальному положенні з оптимальною швидкістю задля якомога ефективнішого «забезпечення польоту м'яча». Ефективне використання сегмента кінетичного ланцюга створює набагато більшу швидкість ракетки, ніж його складових. Натомість розірваний кінетичний ланцюг спричиняє менш оптимальну швидкість польоту м'яча і навіть може призвести до травмування. Однак насправді рух кінетичного ланцюга і показник швидкості польоту м'яча неможливо помітити лише за допомогою обсерваційного методу. Тому для діагностики цього процесу необхідне впровадження спеціальної технології.

Мета роботи. Метою цього дослідження було розробити цифрову систему програмного забезпечення для вимірювання показників швидкості польоту м'яча на основі кінетичного ланцюга удару під час виконання подачі.

Матеріали та методи. У представлений науковій праці застосовано методику науково-дослідних та дослідно-конструкторських робіт. Збір даних здійснювався шляхом фіксації відеозаписів ударів під час подачі 10 спортсменів-професіоналів. Згодом отримані відеозаписи були проаналізовані за допомогою програмного забезпечення для перевірки кутів їхнього руху.

Результати. Результати показали, що середні кути мали наступні параметри: лікоть = 120.490, плече = 166.010, стегно = 165.330, коліно = 165.880, надп'яtkово-гомільковий суглоб = 173.790, а швидкість польоту м'яча = 24.33 м/с.

Висновки. На основі проведеного дослідження зроблено кілька висновків. По-перше, значніша частина кінетичної енергії сили, що створюється під час виконання подачі, розвивається у ногах і тулубі. Кожен сегмент генерував силу і діяв як структура-стабілізатор задля активності наступного сегмента. У такий спосіб вироблялося п'ятдесят один відсоток кінетичної енергії і від 54 до 60 відсотків загальної сили. По-друге, кінетичний ланцюг був орієнтований на зміну лінійного або прямолінійного імпульсу у кутовий або обертальний момент навколо стійкої опори. По-третє, кожен сегмент мав фази нахилу або стабілізації та прискорення. По-четверте, потрібно збільшити діапазон та швидкість рухів в суглобах, зокрема в плечах. Зрештою, розірваний сегмент або кінетичний ланцюг зменшував кінцеву силу або енергію, необхідну для руху м'яча, створюючи величезний тиск на навколишні сегменти. Зниження кінетичної енергії на 10% від стегна або тулуба до плеча під час виконання подачі вимагало збільшення обертання плеча на 14% або збільшення маси плеча на 22%, щоб створити аналогічну кінетичну енергію для кистей рук і ракетки. Серед причин розриву кінетичного ланцюга можна виділити кілька основних: м'язова слабкість, відсутність гнучкості, травми суглобів та погана механіка удару.

Ключові слова: кінетичний ланцюг, технологія, подача, теніс.

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Software and Hardware Control System for Implementing the Balance Error Scoring System

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Abstract

Objectives. The study aimed to determine the degree of reliability and validity of the “Balance Error Scoring System” (BESS) for students after blast TBI implemented by the developed software and hardware control system.

Material and methods. The experiment was attended by 1st-year students (28) after blast TBI in remission, provided that there were no complications and post-concussion syndrome. The theoretical level of scientific research involved using the methods of analysis, synthesis, induction, deduction and interpretation. The developed software and hardware tools used the method of technical modelling. The experimental data presented in this study were obtained by using the BESS in the process of pedagogical testing, which was processed by methods of mathematical statistics.

Results. The result of our scientific research was the development of software and hardware control system for the implementation of BESS based on the integration of hardware and data processing algorithms. In the construction of the software-technical control system for the implementation of BESS, elements of the latest generation of electronic technology were used, namely: piezoelectric pressure sensors, Force-Sensitive Resistor, MPU-9250 sensor module – System-in-Package, which consists of a gyroscope, accelerometer and integrated Digital Motion Processor, as well as Arduino Mega board. For real-time data transmission to the PC screen and smartphone, wireless modules HC-05 (Bluetooth) or ESP32 (Wi-Fi) were used. To implement the tasks of processing BESS data, application software was developed, and neural network technology was used to process BESS results. Statistical processing of BESS results obtained by two methods of registering results revealed that the level of reliability and validity when the results were marked by an expert corresponded to the level of “low” and “medium”. In the case of recording BESS results by the software-technical control system, the level of reliability and validity of the studied parameters reached the limit of “high”.

Conclusions. The findings indicate that the use of advanced technologies and dependable automated control systems in inclusive physical education for the collection, careful study and analysis of test data ensures the generation of high-quality, trustworthy information, which serves as the basis for creating reliable and scientifically sound programs for restoring damaged functions after blast TBI.

Keywords: student, blast TBI, physical education, testing, inclusion, control, balance, reliability, validity.

Introduction

Problem statement. Since the beginning of the full-scale war, the aggression of the Russian Federation has had

particularly severe consequences for the most vulnerable categories of the population, such as people affected by the war, as a result of injuries. In the situation of prolonged active hostilities on the territory of Ukraine and daily terrorist attacks, the scale of the catastrophe is increasing every day. This is a factor in the steady increase in the number of people who have sustained explosive injuries (Blavt et al., 2024).

According to (Chernenko, 2022; Ghandour et al., 2022), mild concussion due to blast injury (blast TBI) accounts

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for half of all war injuries, which can be sustained equally by combatants and civilians. Blast injuries are the leading cause of TBI in war zones (Ling, Ecklund, & Bandak, 2015; Haydel, & Lauro, 2024). Moreover, mild TBI is almost 10 times more common than moderate and severe trauma (Dewan et al., 2019; Buckley, Oldham, & Caccese, 2016), but the exact prevalence is unknown (Kovacs, Leonessa, & Ling, 2014). With an additional 30% of latent cases (NAMS) added to this number, blast TBI has become a growing concern (DePalma, 2015).

Blast TBI has been called a «silent epidemic» because it contributes to disability and long-term disability among young people more than any other injury (Dewan et al., 2019; Marcus et al., 2019). It is recognized (Krueger, et al., 2021) as a factor of economic and social costs and deterioration of quality of life.

Along with the fact that the prevalence of blast TBI is a serious problem for the healthcare sector (Ling, & Ecklund, 2011), because the number of students after blast TBI in higher education institutions is growing (Blavt et al., 2024), this problem is becoming one of the central areas of higher education.

Analysis of recent research and publications. In higher education, the function of adaptation of students affected by the war and rehabilitation of damaged functions is entrusted to inclusive physical education (Blavt et al., 2023). At the same time, inclusion is recognized (Lieberman, Houston-Wilson, & Grenier, 2024; Barber, & Walters, 2024) as a norm of the modern educational environment.

It has been researched (Denby, et al., 2020; Sudhakar, et al., 2023; Du et al., 2023) that blast TBI causes varying degrees of injury severity. It has been proven (Zairinal, Malufti, & Ramli, 2023; Abebe, Alemu, & Sorato, 2024; Zhao et al., 2023) that such injuries are accompanied by significant disorders in the state of the body's functional systems, in particular, the vestibular system (Taylor et al., 2022; Akin et al., 2017; Wood et al., 2022).

In particular, vestibular dysfunction is a common consequence of blast TBI, which can prolong recovery time (Mucha, Fedor, & DeMarco, 2018; Akin et al., 2022; Alkathiry et al., 2019). It has been established (Kuo et al., 2021; Kontos et al., 2018; Zollman, 2021) that balance is a widely recognized marker of control over the recovery process after blast TBI.

Instead, it has been studied (Murray et al., 2019; Akin et al., 2017; Akin, & Murnane, 2011; Leland et al., 2016) that postural instability is the main indicator of concussion. Recovery from dizziness and imbalance after mTBI is an area of ongoing research (Taylor et al., 2022; Romero et al., 2023; Alkathiry et al., 2019).

It has been argued (King et al., 2014; Leland et al., 2016; Prevention, mitigation, and treatment of blast injuries) that the persistence of imbalance symptoms after blast TBI is associated with the lack of constant control of this process. It has been determined (Joyce et al., 2022; Akin, & Murnane, 2011; Babu, Schutt, & Bojrab, 2019) that the diagnosis of disorders associated with blast TBI should be largely based on the results of objective testing to understand the effectiveness of interventions. On the other hand, it is believed (Fusco et al., 2020; Park, & Lee, 2014) that assessing test authenticity parameters provides an idea of the real effect of rehabilitation interventions.

At the same time, in inclusive physical education in accordance with the modern progress and direction

of European educational integration, it seems possible to ensure the effectiveness of control in case of implantation of modern devices, programs and systems in the testing process (Colls, 2023; Blavt et al., 2023; Varga, & Révész, 2023).

The purpose of the study is to determine the degree of reliability and validity of the «Balance Error Scoring System» for students after blast TBI implemented using the developed software and hardware control system.

Materials and Methods

Research Methods

The choice of research methods was made following the principles of systematicity and structuredness at the empirical and theoretical stages, which were performed in the proper sequence. The theoretical level of the study involved a practice-oriented approach, subject to the requirements of systematicity and the use of methods of analysis, synthesis, induction and deduction, and interpretation.

The identification, evaluation and generalization of scientific research data were carried out at the empirical level of the study. The experimental data in the study were obtained during testing, which was generalized, described, systematized and classified.

In choosing a test for measuring static balance, we were guided by the criteria that determine the usefulness of a test in certain studies. That is the possibility of its application in the conditions of physical education of students, as well as efficiency in terms of time and costs.

Traditionally, the «Balance Error Scoring System» (BESS) test is used to monitor the recovery process after mild TBI, which is a short, simple static balance test (Joyce et al., 2022). The BESS is a widely used tool for assessing mild TBI (Mathiasen et al., 2018), which is recognized as an effective modern tool (Caccese, & Kaminski, 2016; Napoli et al., 2016).

The test procedure. The balance testing consists of three stances on two different surfaces. The three stances are double leg stance, single leg stance and tandem stance. The two different surfaces include both a firm (ground) and foam surface. (Fig. 1).

The barefoot student should take a certain standing position with hands on hips and eyes closed with a constant foot position depending on the stance. The trial is 20 seconds. Count the number of errors from the proper stance (Balance_Error_Scoring_System).

The BESS is calculated by adding one error point for each error during the 6 20-second tests. The maximum number of errors for one exercise is 10. Errors include moving the hands away from the iliac crests, opening the eyes, stumbling or falling, abducting or flexing the hip more than 30 degrees, lifting the forefoot or heel above the test surface, and staying out of the proper test position for more than 5 seconds.



Fig. 1. Scheme of the BESS test

Study Participants

The 28 first-year students in remission after blast TBI took part in the experiment, from Lviv Polytechnic National University, Kamianets-Podilskyi National Ivan Ohiienko University and Kremenets Regional Humanitarian Pedagogical Institute named after Taras Shevchenko.

All students involved in the experiment had no complications. The limitations of this study were taken into account due to the small sample size and the age of the participants (from 19 to 23 years). The study sample included students exclusively after mild blast TBI with no post-concussion syndrome and musculoskeletal disorders that would affect balance indicators. The latter is justified by the need to interpret the effectiveness of BESS always in the context of all clinical information.

The students included in the study sample provided written consent to participate anonymously in the experiment, underwent a medical examination, and received the consent of a medical professional to participate in the experiment.

The study was planned and carried out following the principles of bioethics set forth by the World Medical Association (WMA-2013) in the Helsinki Declaration «Ethical Principles of Medical Research Involving Humans» and UNESCO in the «General Declaration on Bioethics and Human Rights».

Research Organization

The applied research was implemented as part of a university course on inclusive physical education. The comprehensive strategy for the implementation of the study included two stages. In the first stage, a software and hardware intelligent control system was created to implement BESS. In the second stage, the data on the test results were collected in two ways, processed and systematized.

To ensure that the BESS results were not misinterpreted, the testing was conducted anonymously by independent experts in the first case and with the use of a software and hardware control system in the second. In this way, in the second case, they tried to eliminate registration errors and, therefore, subjective interpretation of the collected data.

The essence of the empirical stage is to collect reliable information on the BESS results and ensure their availability.

Statistical Analysis

Statistical methods were applied given the need for the study that the selected outcome measure should be shown to verify a specific aspect of the quality under test (validity). At the same time, the repeatability of a certain set of research results (reliability) reflects the degree to which they can be reproduced in an identical study (AQR).

Validity, which characterizes the quality of validity, impartiality and correctness (Vocabulary). In the context of our study, it is important that a test has construct validity if it can discriminate between individuals known to have a particular condition (Portney, & Watkins, 2009).

Test-retest reliability and validity were determined by correlation analysis. The level of correlation was used as a measure for interpreting the research materials.

The organization and processing of empirical data was realized using special mathematical software SPSS Version 22.0 (IBM Corporation).

Results

It has been determined (Ponsford et al., 2024; Mucha, Fedor, & DeMarco, 2018) that TBI usually leads to short-term, spontaneously resolving neurological impairment that largely reflects functional rather than structural brain damage. Accordingly, balance, which is controlled by the combined input of the visual, vestibular, and somatosensory systems, is a fairly common consequence of TBI (Mullally, 2017). Deviations in Static balance, which is an indicator of the synthesized activity of the somatosensory, visual, and vestibular systems to achieve steadiness (Bell et al., 2011), may be symptoms of certain diseases (Marcus et al., 2019). Balance is assessed within the concept of coordination and is defined as the ability to keep the center of gravity of the body on a supporting surface (Ross et al., 2023).

Therefore, to implement BESS, we have developed a software and hardware control system. The system is based on the integration of hardware and data processing algorithms. Thus, we made it possible to accurately analyze the control data and eliminate the subjective influence of the human factor.

The basis of the software and hardware control system for the implementation of BESS is the Force Sensitive Resistor piezoelectric pressure sensors, which are placed in the soft mat used to perform BESS. The Force Sensitive Resistor continuously monitors the weight distribution, recording any deviations, such as the movement of the center of gravity or a minimal loss of balance (Politanskyi et al., 2024). The sensors used in the development are easy to use, characterized by low power and the ability to operate on batteries (which is extremely important in a situation of limited energy resources). Since the Force Sensitive Resistor operates on 5 volts, it can be connected directly to an Arduino, which is what we did.

Another key component of the software and hardware control system for implementing BESS is the MPU-9250 motion sensor module, which is placed on the student's body. The MPU-9250 is a System in Package consisting of a gyroscope, accelerometer, and integrated Digital Motion Processor. The module, which is attached to the student's belt or shoes, tracks body tilts and angular displacements in the front/back and left/right planes that occur during the test.

In our development, we used an improved version of the MPU-9250 with an activity detection and 9-axis calibration system – MotionFusion. MotionFusion algorithms process information from all sensors, forming a complete set of data on any displacements of the student's body that occur during the test. Analyzing this data allows us to detect minimal balance disorders. To integrate multiple sensors into one system, we used the Arduino Mega (the latest version of the top-of-the-line Arduino microcontroller board), which has a sufficient number of input ports to read signals from all connected sensors (Mykytyuk et al., 2024).

The signals received by the Force Sensitive Resistor and Digital Motion Processor when the student performs the BESS are sent to the Arduino Mega hardware computing platform, which acts as a hub for data collection. The Arduino

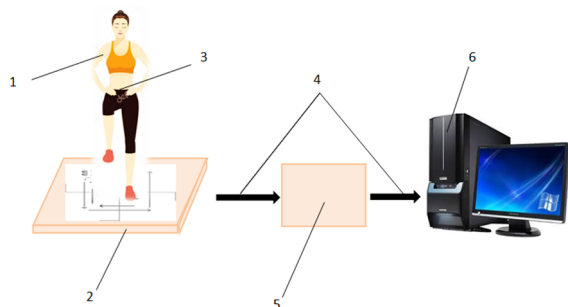


Fig. 2. Scheme of BESS implementation using a software and hardware control system: 1 – student, 2 – Force Sensitive Resistor, 3 – MPU-9250 motion sensor module, 4 – infrared communication lines, 5 – Arduino Mega hardware computing platform, 6 – PC

Mega board includes a microcontroller with I/O elements and a Processing/Wiring development environment that performs the primary processing of the Force Sensitive Resistor and System in Package signals and identifies changes in the weight load.

To transmit data in real-time, we used wireless modules such as HC-05 (Bluetooth) or ESP32 (Wi-Fi), which realize the presentation of results on a PC and smartphone screen.

The developed software and hardware control system for the implementation of BESS provides for the collection and processing of test data in real-time. Application software was developed to implement the tasks of BESS data processing, and neural network technology was used to process the BESS results data.

In the second stage of the study, when the BESS data were collected in two ways, they were processed and systematized. The results of statistical processing of BESS data are presented in Tables 1 and 2.

Thus, according to the results of the statistical processing of the BESS results, the following was found: the level of reliability and validity, when the results were noted by the expert, corresponded to the level of «low» and «medium». However, when the results were recorded by the software and

Table 1. Reliability and validity of the BESS for students after blast TBI in the firm surface (n = 28)

Statistical parameters	BESS tasks and measurement results in the firm surface (к-сть помилок)					
	Double Leg Stance		Single Leg Stance		Tandem Stance	
	E	ПТИС	E	ПТИС	E	ПТИС
Mean	3.67	3.21	4.1	3.3	2.95	1.93
± SD	3.01	2.01	2.88	1.93	2.15	1.82
Median	3.01	2.93	3.88	3.01	2.31	1.55
V (%)	31.24	20.51	30.9	23.14	35.94	22.81
rtt						
reliability	0.401	0.899	0.376	0.917	0.482	0.904
validity	0.216	0.583	0.212	0.611	0.233	0.678

*Note: E – experts, CS – software and hardware control system

Table 2. Reliability and validity of the BESS for students after blast TBI in the foam surface (n = 28)

Statistical parameters	BESS tasks and measurement results in the foam surface (к-сть помилок)					
	Double Leg Stance		Single Leg Stance		Tandem Stance	
	E	ПТИС	E	ПТИС	E	ПТИС
Mean	5.12	4.17	5.32	3.45	4.18	5.33
± SD	2.21	1.18	2.34	2.21	2.09	2.13
Median	3.88	3.02	3.56	2.14	3.02	4.55
V (%)	34.11	25.51	31.43	20.85	31.21	19.28
rtt						
reliability	0.488	0.919	0.418	0.955	0.433	0.917
validity	0.189	0.612	0.201	0.688	0.223	0.654

*Note: E – experts, CS – software and hardware control system

hardware control system, the level of reliability and validity of the studied BESS parameters reached the «high» level.

Dicussion

Our scientific research is justified by the fact that testing in physical education is an effective tool for assessing various aspects of students' physical and personal development (Colls, 2023). We support the thesis that motor skills assessment is positioned as a tool to promote inclusive education by recognizing the unique abilities and challenges of each student (Barber, & Walters, 2024; Blavt, & Gurtova, 2024).

Our study expands on the importance of balance as a component in concussion assessment (Murray et al., 2019; Matuszak et al., 2016), which can serve as a guide for rehabilitation in individuals after TBI (Taylor et al., 2022). We support the need for a comprehensive assessment of vestibular function and balance in individuals following blast-related injury (Akin et al., 2022; Wood et al., 2022).

Determining validity and reliability are considered (Ng, & Samsudin, 2024; Barlow et al., 2011) to be necessary steps in evaluating an instrument. This is in line with the findings that manually obtained balance scores cannot be accurate and do not detect changes that cannot be recognized by the naked eye (Rochefort et al., 2017; Prangle, Aggerholm, & Cinelli, 2017; Ross et al., 2023).

The study is in line with the current state of the art in the field: it is consistent with the data (Blavt et al., 2024; Fusco et al., 2020; Mykytyuk et al., 2022) that the use of computerized programmable devices in testing is an effective means of achieving objectivity in the testing process. Our research is motivated by the need to develop an inexpensive and widely available balance test instrument (Park, & Lee, 2014; Alberts et al., 2015), given that the balance test provides important information such as a standard for assessing functional recovery (Park, & Lee, 2014; Bell et al., 2011).

Our study is in line with the results of scientific research (Fusco et al., 2020; Park, & Lee, 2014; Ross et al., 2023) that computerized instrumented devices have the potential to become the mainstream devices for balance assessment (Caccese, & Kaminski, 2016).

It has been reported that the use of technical means (Goldie, Bach, & Evans, 1989), in particular, portable sensors (King, et al., 2014; Napoli, et al., 2016) in balance control, including after TBI, ensures the objectivity of measurements.

Our study confirms the results (Bell et al., 2011; Ross, Hoch, Malvasi, Cameron, & Roach, 2023; Caccese, & Kaminski, 2016) that the reliability of the overall BESS assessment ranges from poor to medium when performed by a specialist.

The reliability of the BESS has been studied for specific populations, in particular, in Military Cadets (Bell, 2011; Ross et al., 2023); middle school and high school population (Barlow et al., 2011); undergraduate students (Planchet et al., 2023); among NCAA Division-I Football Athletes (Mathiasen et al., 2018); in healthy young athletes (Valovich McLeod et al., 2004); in concussed athletes on the sidelines (Caccese, & Kaminski, 2016); a healthy population (Tao et al., 2020); with moderate-to-severe TBI (Joyce et al., 2022); in US military personnel (Kontos et al., 2021).

We first investigated the use of BESS to assess the state of balance for students after blast TBI and experimentally established the level of reliability and validity of BESS, which was implemented using a software and hardware control system for the implementation of BESS.

Conclusions

Most of the changes in national educational policy were aimed at adapting higher education to the new military realities. Important developments in this area are aimed at rethinking the educational process of vulnerable categories of students, in particular those who received TBI blasts as a result of Russia's full-scale invasion of Ukraine.

A software and hardware control system was developed to implement BESS for students after blast TBI based on the integration of modern hardware and data processing algorithms. Application software has been developed to implement the tasks of BESS data processing, and neural network technology has been used to process the BESS results data.

The presented software and hardware control system for the implementation of BESS provides for the collection and processing of test control data in real-time, which is a factor in their relevance and will be especially noticeable in short-term studies. Its use ensures the objectivity, accuracy and reliability of the control process.

Establishing a measure of reliability and validity of the BESS for students after blast TBI proves the advantage of automated controls in ensuring the impartiality and reliability of the testing process. According to the empirical data obtained from the experiment, the level of the studied BESS indicators measured using the software and hardware intelligent control system for students after blast TBI reached the "high" mark.

The use of advanced technologies and reliable automated control systems in the practice of inclusive physical education for the collection, thorough study and analysis of test data provides the generation of high-quality reliable data, which is the basis for the creation of effective scientifically based programs for the restoration of damaged functions after blast TBI.

Conflicts of Interest

No conflicts of interest exist.

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Програмно-технічна система контролю для реалізації системи підрахунку помилок балансу

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 9 с., 2 табл., 2 рис., 69 джерел.

Мета дослідження у визначенні ступеню надійності та валідності «Системи підрахунку помилок балансу» для студентів після вибухової черепно-мозкової травми реалізованого розробленою програмно-технічною системою контролю.

Матеріал та методи. У експерименті прийняли участь студенти I-го курсу навчання після вибухової черепно-мозкової травми у стані ремісії, за умови відсутності ускладнень та постконтузійного синдрому. Теоретичний рівень наукового пошуку передбачав застосування методів аналізу, синтезу, індукції та дедукції, інтерпретації. У створенні програмно-технічного засобу застосовано метод технічного моделювання. Експериментальні дані у дослідженні отримані шляхом використання «Системи підрахунку помилок балансу» у процесі педагогічного тестування, які оброблено методами математичної статистики.

Результати. Підсумком нашого наукового пошуку є розроблення програмно-технічної системи контролю реалізації BESS на основі інтеграції апаратного забезпечення та алгоритмів обробки даних. У побудові програмно-технічної системи контролю для реалізації BESS використано елементи останнього покоління електронної техніки, а саме: п'єзоелектричні сенсори тиску Force Sensitive Resistor, сенсорний модуль MPU-9250 – System in Package (SiP), який складається з гіроскопа, акселерометра й інтегрованого Digital Motion Processor (DMP), плати Arduino Mega. Для передачі даних у реальному часі на екран ПК та смартфона нами використано бездротові модулі HC-05 (Bluetooth) або ESP32 (Wi-Fi). Для реалізації завдань опрацювання даних BESS розроблено прикладне програмне забезпечення, а для обробки даних результатів BESS використано технологію нейромережі. Статистичним опрацюванням результатів BESS, які отримано двома способами реєстрації результатів з'ясовано, що рівень надійності та валідності коли результати відмічались експертом відповідні рівню «низький» та «середній». У разі запису результатів BESS програмно-технічною системою контролю рівень досліджуваних параметрів надійності та валідності досягав межі «високий».

Висновки. Використання у практиці у інклюзивному фізичному вихованні передових технологій та надійних автоматизованих систем керування для збору, ретельного вивчення та аналізу даних тестових випробувань забезпечують генерування високоякісних достовірних даних, що є основою у створенні надійних та науково обґрунтованих програм відновлення ушкоджених функцій після вибухової черепно-мозкової травми.

Ключові слова: студенти, вибухова черепно-мозкова травма, фізичне виховання, тестування, інклюзія, контроль, баланс, надійність, валідність.

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The Impact of Targeted Soccer Training Interventions on YO-YO Intermittent Recovery Test Performance in University-Level Soccer Players

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Abstract

Background. Soccer demands high endurance, speed, and aerobic capacity, making fitness a key performance factor. The Yo-Yo Intermittent Recovery Test Level 1 (YYIR1) is a valid field test to assess these attributes in soccer players.

Objectives. This study aimed to evaluate the effect of a 12-week targeted soccer training program on aerobic endurance in university-level male soccer players.

Materials and methods. A quasi-experimental pretest-posttest design was used, involving 32 university-level male soccer players (aged 17-25) from Visva-Bharati University. Participants underwent a 12-week targeted soccer training program. Aerobic endurance performance was assessed using the YYIR1 test, evaluating accumulated distance, cumulative time, and VO_2max before and after the intervention. Data were analyzed using paired-sample t-tests, with a significance level set at $p < 0.05$.

Results. Among 32 university-level male soccer players, significant improvements were observed in the post-intervention period: accumulated distance (mean increase = 312.5 meters, $d = 1.70$), cumulative time (mean increase = 2.54 minutes, $d = 1.80$), and VO_2max (mean increase = 2.62 ml/kg/min, $d = 1.72$), all with $p < 0.001$.

Conclusions. According to the study, it was found that the 12-week targeted soccer training intervention led to statistically significant enhancements in aerobic endurance capacities among university-level soccer players, as demonstrated by improvements in YYIR1 test outcomes.

Keywords: soccer, Yo-Yo Intermittent Recovery Test, VO_2max , aerobic fitness, endurance training.

Introduction

Soccer is one of the most challenging sports in the world (Toparlak & Salas, 2022; Gurău et al., 2023). Players must possess strong physical, mental, technical, and tactical qualities to perform at an elite level (Toselli et al., 2022; Verma & Dabshede, 2024). Physical fitness is one of the most critical factors for a soccer player to perform at their best on the field (Iaia, Rampinini, & Bangsbo, 2009). Endurance capacity is vital in soccer, which requires sustained performance

over 90 minutes. During the game, players face different situations where they need to showcase their skills, such as demands like speed, endurance, agility, and strength. Players must maintain high performance throughout the match, demanding a high level of physical fitness. Modern soccer requires high endurance, speed, strength, and coordination skills (Andrzejewski et al., 2015). Therefore, players must develop strong aerobic and physical qualities to meet the demands of the game. Various lab tests can measure Aerobic Fitness (VO_2max) accurately. However, for this study, the VO_2max is calculated through the reference table of the Yo-Yo Intermittent Recovery Test, as this table was prepared by testing various subjects (Bangsbo, Iaia, & Krustrup, 2008). Therefore, the YYIR1 is very popular for ballgame players to measure aerobic fitness quality (Castagna et al., 2008).

The Yo-Yo Intermittent Recovery Test Level 1 (YYIR1), developed by Dr. Jens Bangsbo, is a widely used test to evaluate an athlete's ability to repeatedly perform high-intensity intervals with brief recovery periods. It is especially relevant for soccer players, as the sport demands frequent sprints interspersed with short recovery phases. The yo-yo intermittent recovery test is available in two versions: version 1 is for beginners, and version 2 is for advanced players. The trial starts with a beep sound, with certain levels where the speed increases as the time of completing the levels decreases in different groups (Bangsbo, Iaia, & Krstrup, 2008).

The purpose of the YYIR1 is to determine the repeatedly performed interval for a prolonged period. It is a field test assessing the physical performance of athletes. The test layout is 20×5 meters for the YYIR1, whereas the 20-meter intervals are back and 5 meters for recovery. The subjects will get 10 seconds of recovery time after every 40 meters (Bangsbo, Iaia, & Krstrup, 2008).

While previous studies have explored aerobic capacity using the YYIR1 in professional or youth athletes, limited research has focused on structured training effects in university-level players in the Indian context. There is a lack of controlled research evaluating the impact of periodized soccer-specific training on aerobic performance in Indian university-level soccer players. This study addresses this gap by applying a periodized training protocol tailored to the inter-university competitive calendar.

Materials and Methods:

Participants

A total of 32 participants, aged between 17 and 25 years (Age = 22 ± 1.78 years), were selected using purposive sampling. No random assignment to groups was performed, as the study involved only one intervention group. All participants were inter-university soccer players from the Visva-Bharati University team, a prestigious Central University recognized as an institute of national importance in Santiniketan, West Bengal, India.

Before selecting the participants, a priori power analysis was performed using G*Power software (version 3.1.9.2, University of Kiel, Germany). The analysis employed an effect size of 0.80, an alpha error probability of 0.05, and a statistical power 0.95 (Kang, 2021). This ensured an adequate sample size to detect meaningful differences or effects.

The sample size determination test revealed a sample size of 23 for the study. However, to compensate for participant attrition, 32 participants were considered as the sample for the study. All the included participants in the study were free from acute or chronic medical conditions. The participants possessing serious medical contraindications (hypertension, recent heart surgery, uncontrolled diabetes) or with significant cognitive impairments, as advised by physicians, precluding them from engaging in vigorous physical activities, were excluded from the study. On average, the participants exercised eleven months per year for at least three years (3.4 ± 0.8 years) with five 150-minute sessions, weekly and one practice match every two weeks and one competition every three months. The research received approval from the Institutional Ethical Committee of Visva-Bharati (A Central University) Santiniketan, West Bengal,

India, ensuring that it adhered to requisite ethical standards and guidelines (VB/IECHR/03/2024) and registered through Clinical Trials Registry-India (CTRI/2025/02/080710, registered on: 17/02/2025). Furthermore, the study adhered to the guidelines outlined in the Declaration of Helsinki (World Medical Association Declaration of Helsinki, 2013). The participants had given written consent after thoroughly understanding the study's objectives, potential benefits, risks, and future implications. See Figure 1 for the study flowchart to illustrate this one-group pretest-posttest quasi-experimental design.

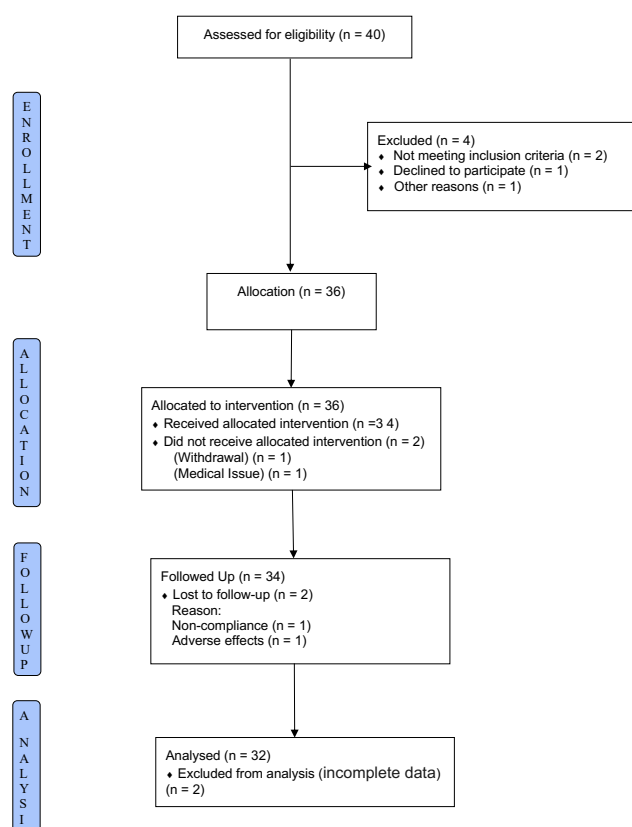


Fig. 1. Study Flowchart for the Quasi-Experimental One-Group Pre-test-Post-test Design

Study Design

The research employed a quasi-experiment utilizing a one-group pretest-posttest design (Figure 1), citing the limited number of participants (Knapp, 2016). The participants were tested before and after the exposure to twelve weeks of the Soccer Training Interventions program. The participants were instructed not to be involved in any other types of physical interventions which might have influenced the sole effect of the Soccer Training Interventions program. The pre-test was completed three days before the start of the training program, whereas the post-test was completed three days after the completion of the twelve weeks of the soccer training program.

Although a control group would strengthen internal validity, logistical challenges, ethical concerns in withholding training, and limited player availability made it impractical. This design still allows for a meaningful evaluation of

within-subject improvements, but generalizability should be interpreted cautiously.

Training Intervention

The 12-week training program was designed to enhance the overall performance of inter-university-level soccer players. It focused on five key areas: strength training, technical skills, speed and agility, endurance, and tactical awareness.

Each week included five training sessions of 150 minutes each, totaling 750 minutes per week. The program integrated strength, endurance, technical, tactical, and speed-focused training tailored for inter-university soccer players. In addition, one full practice match was scheduled every two weeks, and official competitions were held every three months.

Testing Protocol

Yo-Yo Intermittent Recovery Test Level 1 (YYIR1) and the audio for the YYIR1, which Dr. Jens Bangsbo created, were considered for the test. Before the test, all the players were well-instructed and demonstrated with a demo, and then the researcher took the test. The subject stood behind the starting line, started running 20 meters on the sound of 'GO,' and touched the end-bound line with a beep. Again, they will return to the starting line within the beep sound without stopping and rest for 10 seconds in the 5-meter recovery zone for the recovery time. Accumulated distance refers to the total distance (in meters) the participant covers before the test ends. Cumulative time represents the total

Test Course of the Yo-Yo Intermittent Recovery Test

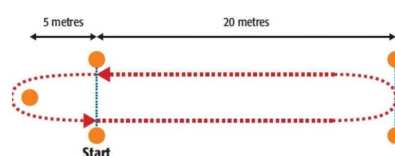


Fig. 2. The test course of the Yo-Yo Intermittent Recovery Test-1. The full course shows the player's movement during the run and the dotted line for the recovery period

duration (in minutes) completed in the test. VO_2 max was estimated using the standard YYIR1 lookup tables Bangsbo et al. (2008) provided based on the total distance covered. In the early stage, the speed was slow, but it got increasingly faster as the test progressed (Sports, 2008).

Statistical Analysis

Descriptive statistics were used to describe the data on the YYIR1 performance of the pre-test and post-test of the soccer player's accumulation distance, cumulative time, and VO_2 max. To ensconce the validity of this study's statistical analysis, the researcher measured the assumption of normality of data. The Shapiro-Wilk test was used to assess the normality of data distribution. The Shapiro Wilk test showed that the data collected from the variable's accumulation distance pre and post-test, Cumulative time pre and post-test, and VO_2 max pre and post-test through the YYIR1 test were normal. Thus, the normality of data further leads to subsequent analysis.

Table 1. Twelve weeks of targeted soccer training intervention

Phase	Weeks	Component	Intensity	Volume/Type	Frequency	Rest Between Sets
1	1–4	Strength Training	70–80% of 1RM	3–4 sets of 8–12 reps	2x/week	60–90 sec
		Technical Skills	Moderate	30–45 min	2x/week	–
		Speed & Agility	Moderate	Short sprints (10–20 m)	1x/week	–
		Endurance	Moderate	Long runs (5–8 km), Intervals	1x/week	–
		Small-Sided Games	Moderate	3v3, 5v5 (20–30 min)	1x/week	–
		Practice Match	Match Intensity	Full 11v11 (60–90 min)	1 match/2 weeks	–
2	5–8	Strength Training	80–90% of 1RM	3–4 sets of 6–8 reps	2x/week	90–120 sec
		Technical Skills	High	45–60 min	2x/week	–
		Speed & Agility	High	Sprints (20–30 m)	1x/week	–
		Tactical Training	Moderate to High	Set-piece positioning drills	1x/week	–
		Small-Sided Games	High	7v7, 9v9 (30–45 min)	1x/week	–
		Practice Match	Match Intensity	Full 11v11 (60–90 min)	1 match/2 weeks	–
3	9–12	Strength Training	70–80% of 1RM	2–3 sets of 4–6 reps	2x/week	60–90 sec
		Technical Skills	High	30 min	2x/week	–
		Speed & Agility	Maximum	Sprints (30–40 m)	1x/week	–
		Tactical Training	Match Intensity	Positional play, set pieces	1x/week	–
		Small-Sided Games	Match Intensity	11v11 simulations (60–90 min)	1x/week	–
		Practice Match	Match Intensity	Full 11v11 (60–90 min)	1 match/2 weeks	–
		Competition	Peak Intensity	Full game (90 min)	1 competition/3 months	–

A dependent t-test was computed as inferential statistics to compare the difference between the accumulation distance pre-test with the post-test, Cumulative time pre-test with the post-test, and $VO_2\text{max}$ pre-test with the post-test. In addition to the t-test results, the effect size was ascertained using Cohen's d, and the 95 % Confidence Interval (CI) was delineated. The level of significance was set at $p \leq 0.05$. All analyses were carried out using JAMOV Version 2.4 software.

Results

In Table 2, the descriptive and inferential statistics were applied to acquired data from accumulation distance (pre-test and post-test), Cumulative time (pre-test and post-test), and $VO_2\text{max}$ (pre-test and post-test). Significant differences were found between the accumulated distance pre-test with the post-test, cumulative time pre-test with the post-test, and $VO_2\text{max}$ pre-test with the post-test, as the p-value was $p < 0.05$.

The descriptive statistics of aerobic-endurance variables from the Yo-Yo Intermittent Recovery Test Level 1 (YYIR1) indicate a significant improvement in the participants' performance following the intervention. The accumulated distance (AD) covered increased from a pre-intervention mean of 1020.00 meters (SD = 980.00) to a post-intervention mean of 1332.50 meters (SD = 1320.00), reflecting enhanced endurance capacity. Similarly, the cumulative time (CT) improved from a mean of 8.45 minutes (SD = 8.19) to 10.99 minutes (SD = 10.84), indicating better cardiorespiratory fitness. Furthermore, $VO_2\text{max}$ (VO) increased from 44.97 ml/kg/min (SD = 44.63) to 47.59 ml/kg/min (SD = 47.48), suggesting a positive impact on aerobic fitness levels. Notably, the skewness values for all variables decreased post-intervention, indicating a more balanced and consistent performance distribution among the participants. Overall, the results demonstrate the effectiveness of the training intervention in enhancing aerobic endurance and cardiorespiratory performance in inter-university soccer players. Figures 3 through 8 present the box plots, indicating no significant outliers and that this study's data distribution is normal.

The paired samples t-test results in Table 3 indicate statistically significant improvements in all measured variables following the intervention. The accumulated distance (AD) showed a significant increase from the pre-

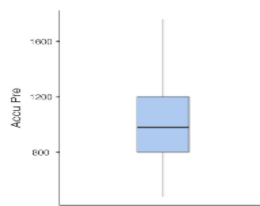


Fig. 3. Pre-Test Accumulated Distance Distribution

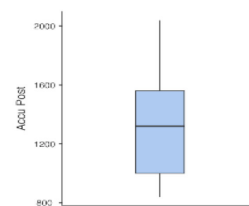


Fig. 4. Post-Test Accumulated Distance Distribution

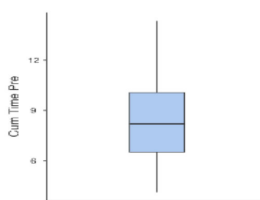


Fig. 5. Pre-Test Cumulative TimeFig

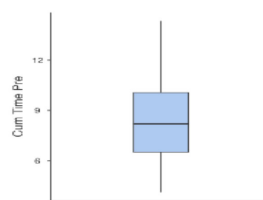


Fig. 6. Post-Test Cumulative Time

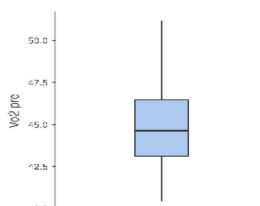


Fig. 7. Pre-Test $VO_2\text{max}$

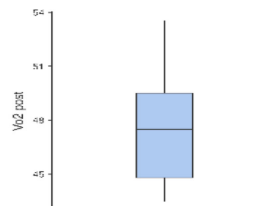


Fig. 8. Post-Test $VO_2\text{max}$

test to the post-test ($t = -9.64$, $df = 31$, $p < .001$), reflecting enhanced aerobic capacity. Similarly, cumulative time (CT) also improved significantly ($t = -10.19$, $df = 31$, $p < .001$), indicating better cardiorespiratory endurance. Additionally, $VO_2\text{max}$ (VO) increased significantly ($t = -9.64$, $df = 31$, $p < .001$), demonstrating improved aerobic fitness. The highly significant p-values ($p < .001$) across all variables highlight the effectiveness of the training intervention in boosting aerobic endurance and cardiorespiratory performance among inter-university soccer players.

These results suggest that the twelve-week training intervention significantly improved soccer-specific endurance and aerobic capacity.

Table 2. Descriptive statistics of aerobic-endurance variables under YYIR1

Group	N	Mean	SE	Median	SD	Min	Max	Skewness	Kurtosis
AD-Pre	32	1020.00	49.29	980.00	980.00	480.00	1760.00	0.586	0.3510
AD-Post	32	1332.50	57.23	1320.00	1320.00	840.00	2040.00	0.462	-0.6998
CT-Pre	32	8.45	0.40	8.19	8.19	4.12	14.30	0.553	0.0959
CT-Post	32	10.99	0.45	10.84	10.84	7.10	16.40	0.411	-0.7395
VO-Pre	32	44.97	0.41	44.63	44.63	40.43	51.20	0.585	0.3484
VO-Post	32	47.59	0.48	47.48	47.48	43.46	53.50	0.462	-0.6995

High standard deviations reflect broad variation in individual performance levels among participants. Note: AD-Pre - Accumulated distance Pre Test, AD-Post - Accumulated distance Post Test, CT-Pre - Cumulative Time Pre Test, CT-Post - Cumulative Time Post Test, VO - Pre - $VO_2\text{max}$ Pre Test, VO - Post - $VO_2\text{max}$ Post Test

Table 3. Paired samples t-test with effect sizes

Variable	t	df	p	Cohen's d
Accumulated Distance	-9.64	31	< .001	1.70
Cumulative Time	-10.19	31	< .001	1.80
VO ₂ max	-9.64	31	< .001	1.72

Effect sizes were calculated using Cohen's d, which indicates large improvements in all performance metrics.

Discussion

The findings of the present study, conducted on 32 young university-level soccer players from Visva-Bharati University, are as follows.

The study's results clearly showed that the targeted soccer training performance on YYIR1 significantly affected the university soccer players' Accumulated distance, Cumulative time, and VO₂max.

The increased performance of accumulated distance, cumulative time, and VO₂max of the soccer players are due to the regular practice of the scheduled training program and the discipline of the players. The capacity for human exercise performance can be enhanced with prolonged exercise training (Hughes, Ellefsen, & Baar, 2018), and increases in mitochondrial enzymes primarily enhance aerobic endurance capability in the muscle (Chandler, 1994). The improvement in stroke volume that results from the enlargement of red blood cells, which adapts independently of changes in red blood cell volume, is a significant factor in training-induced increases in VO₂max (Lundby, Montero, & Joyner, 2017). After 12 weeks, one must increase maximal oxygen absorption, glycolytic enzyme activity, and IR2 test performance (Izzo et al., 2020). Athletes perform better in the Yo-Yo IR tests at greater levels of competitiveness, according to evaluations of elite athletes in various sports involving intermittent exercise (Schmitz et al., 2018). The Yo-Yo intermittent tests, which include data across recreational and competitive levels, age, and gender, are said to be the field testing in soccer that has been meticulously studied (Izzo et al., 2020; Póvoas et al., 2023; Priya, 2024).

Training increases stroke volume and cardiac output, boosting VO₂max (Amanda, Ryan, & Constance, 2011). The trained group experienced a significant increase in VO₂max compared to the untrained group. Highly trained athletes had lower resting heart rates (Whyte, George, & Shavi, 2008). The trained group recovers more quickly from exercise than the untrained group (Dupuy et al., 2024).

In a study, it was demonstrated that Players in the small-sided games (SSG), speed endurance (SER), and combined SSG & SER groups improved Yo-Yo IR1 and Yo-Yo IR2 test performance as compared to the statistically significant control group (Akdoğan et al., 2021).

Various previous training studies have shown that improvement in VO₂peak is closely linked to enhancement in Yo-Yo IR1 test performance (Impellizzeri et al., 2008; Ferrari et al., 2008; Spencer et al., 2005; Hunter et al., 2011). Paes et al., in their study, directly measured VO₂peak during Yo-Yo test performance using portable spirometry. The key finding was that changes in direction affect the physiological parameters evaluated during physical tests (Paes & Fernandez, 2024).

This study has some limitations. First, the quasi-experimental design lacked a randomized control group, restricting causal inferences. Second, the sample was drawn from a single university, limiting the generalizability to other populations. Third, participant self-discipline and external activities were not tightly monitored, which could have influenced results. Future studies should consider using randomized controlled trials with larger and more diverse samples.

Conclusions

The twelve-week targeted soccer training intervention significantly improved Yo-Yo intermittent recovery performances, including accumulative distance, cumulative time, and VO₂max in young university-level soccer players. Statistical analysis, supported by paired samples t-tests, revealed substantial gains in post-test scores compared to pre-test scores, highlighting the program's effectiveness. These improvements can be attributed to regular practice, disciplined training regimens, and the players' adherence to the scheduled training program. These findings suggest that university coaches can effectively implement structured, periodized training interventions to improve aerobic endurance in competitive players, even within academic environments. The enhanced aerobic endurance, increased stroke volume, and greater cardiac output resulting from prolonged training contribute significantly to the observed improvements in performance.

Furthermore, the study aligns with existing research indicating that increased VO₂max and enhanced aerobic capacity are vital components of athletic performance, particularly in sports requiring intermittent and high-intensity efforts, such as soccer. The positive outcomes of this training protocol support its potential application in developing university soccer players' aerobic and endurance capabilities.

Future research should aim to explore the long-term impact of varied training interventions on VO₂max and performance metrics, as well as the effects of individual variability in response to training. Additionally, integrating sport-specific drills and monitoring physiological parameters during training could further optimize the effectiveness of targeted soccer training programs.

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Conflict of Interests

The authors declare that they have no conflicts of interest

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Вплив цільових тренувальних інтервенцій з футболу на результативність Йо-Йо тесту переривчастого відновлення у футболістів університетського рівня

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 7 с., 3 табл., 8 рис., 28 джерел.

Історія питання. Гра у футбол вимагає високої витривалості, швидкості та аеробної здатності, що визначає фізичну підготовленість ключовим фактором результативності. Йо-Йо тест переривчастого відновлення рівня 1 (Yo-Yo Intermittent Recovery Test Level 1, YYIR1) є достовірним польовим тестом для оцінки зазначених якостей футболістів.

Мета дослідження. Це дослідження мало на меті оцінити вплив 12-тижневої цільової програми тренувань з футболу на аеробну витривалість футболістів-чоловіків університетського рівня.

Матеріали та методи. У дослідженні застосовано квазіекспериментальний дизайн передтестового і післятестового етапів за участю 32 футболістів-чоловіків університетського рівня (віком 17-25 років), які навчалися в університеті Вісва-Бхараті (Visva-Bharati University). Учасники пройшли 12-тижневу цільову програму футбольних тренувань. Показники аеробної витривалості оцінювались за допомогою тесту YYIR1, який визначав акумульовану дистанцію, кумулятивний час та рівень максимального споживання кисню (VO_{2max}) перед та після завершення інтервенції. Аналіз даних проводився із використанням t-критеріїв для парних вибірок, рівень значущості встановлено на позначці $p < 0,05$.

Результати. У постінтервенційному періоді серед 32 футболістів-чоловіків університетського рівня спостерігалися значні покращення показників: акумульованої дистанції (середній приріст = 312,5 метрів, $d = 1,70$), кумулятивного часу (середній приріст = 2,54 хвилини, $d = 1,80$) та VO_{2max} (середній приріст = 2,62 мл/кг/хв, $d = 1,72$), усі показники становили $p < 0,001$.

Висновки. Згідно з результатами дослідження встановлено, що 12-тижнева цільова тренувальна інтервенція з футболу сприяла статистично значущому покращенню можливостей аеробної витривалості у футболістів університетського рівня, про що свідчать поліпшення показників за результатами тесту YYIR1.

Ключові слова: футбол, Йо-Йо тест переривчастого відновлення рівня 1, VO_{2max} , аеробна підготовленість, тренування на витривалість.

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Assessing the Efficiency of Reduced Positional Games in Soccer: A Multivariate Analysis of Technical and Tactical Indicators According to Different Playing Systems

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Abstract

Background. Reduced positional games (RPG) are considered as a recognized training method for developing the physical, technical and tactical qualities of young footballers. They simulate real-life match situations, encouraging frequent interaction with the ball and rapid tactical decisions. Adapted to the specific needs of players according to their position, RPG contribute to improving physical fitness, game intelligence and team cohesion.

Objectives. The study aimed to assess the impact of RPG on players' technical and tactical performance, comparing them to standard training. It seeks to determine how RPG optimize key indicators such as possession, passing, shooting, goals scored and error reduction, while exploring their influence on tactical synchronization and team cohesion.

Materials and methods. The study involved 30 matches between five experimental teams and five control teams. The protocol adopted a mixed factorial design, incorporating both between-subjects and within-subjects factors. The between-subjects factor "Group" comprises two levels (experimental teams and control teams), while the within-subjects factors "Match" (three successive matches) and "Playing system" (two tactical configurations: 1-3-2-1 system and 1-2-3-1 system) make it possible to examine variations in performance indicators as a function of the playing context.

Results. The results of this study showed that teams trained with RPG significantly improved their performance. Ball possession increased by 24 %, completed passes by 106 %, and shots by 50 %. Furthermore, it was noted an increase of 43 % in goals scored, while passes lost and goals conceded decrease by 22.6 % and 29 % respectively. These benefits are independent of the game system used, and JRP also enhances communication and synchronization between players.

Conclusions. RPG are an effective training tool for improving players' technical and tactical performance. Applying this approach increases possession, passing, shooting and goals scored, while reducing errors and goals conceded. These findings offer promising prospects for coaches, bringing training methods into line with the demands of modern soccer and fostering players' individual and collective development.

Keywords: reduced positional games, system of play, training, technical, tactical, soccer.

Introduction

Positional short games are widely recognized as a means of training young footballers to improve physical, technical and tactical qualities. This training method creates a competitive environment that simulates real match situations, which is beneficial for the rapid development of young players. Sessions structured around specific themes, adapted to stimulate both the individual and collective

development of players (Slaidiņš & Fernāte, 2021). The interaction of these games with different game systems can potentially accelerate the acquisition of these essential skills, by adapting exercises to the specific needs of players according to their position and role in the team (Clemente et al., 2021).

Small-group soccer matches are generally modified versions of standard soccer matches designed to focus on specific training objectives or to adapt the game to fewer players. They are scaled-down versions of full soccer matches, generally involving fewer players and often played on smaller pitches. They are designed to increase player engagement and opportunities to train on the tactical and

technical aspects of the game (Clemente et al., 2021). In the context of soccer training, RGP are used as a training tool to develop players' skills, decision-making abilities and fitness in a more concentrated and intense environment (Castillo et al., 2020). Matches in reduced positional configurations are crucial in youth soccer for player development. They allow young players to have more frequent contact with the ball compared to full games, improving their ball-handling skills, understanding of space and movement, and overall game intelligence (Errama et al., 2024).

The physical aspect of reduced games manifests itself in a significant increase in intensity linked to reduced playing spaces (Martone et al., 2017), requiring quick reactions and decisions. This higher intensity is compared to match conditions, improving players' overall fitness. In addition, positionally adapted RGP allow specific physical aspects to be targeted, such as endurance, speed and agility, which are crucial for modern soccer (Barba et al., 2020). Arslan et al. (2020) compared the effects of high-intensity interval training and short games on the physical and technical performance of young soccer players. They observed that role-specific exercises increase the intensity of physical activity, leading to improvements in players' anaerobic and aerobic capacity. This ability to combine physical development with tactics offers a double benefit, making RGP a particularly valuable training tool.

In a confined space, the adoption of reduced play in training programs for young footballers is an increasingly common practice, recognized for its effectiveness in the integrated development of athletic skills. This method promotes accelerated learning through frequent interaction with the ball and constant exposure to tactical decisions (Dina, 2022). Players are forced to perfect technical skills such as ball control, accurate passing, and the ability to maintain possession under pressure. This helps them not only to improve their individual performance but also to synchronize their actions with those of the team, which is crucial to their personal and collective technical development (McCalman et al., 2021). Reduced play, characterized by matches on smaller pitches and fewer players, intensifies interactions with the ball and multiplies opportunities for play, facilitating technical improvement and rapid decision-making (Clemente et al., 2021).

Reduced games with position make it easy to learn and experiment with different tactical configurations and strategies. They encourage players to make quick and accurate decisions, which improves their tactical understanding of the game. These direct experiences enable players to adapt quickly to changes in the game and better respond to tactical challenges posed by opponents (Clemente et al., 2020).

Overall, the integration of positional RGP into daily training programs represents a comprehensive approach to developing the key performance attributes required for soccer excellence. In terms of performance of technical-tactical actions, it has been concluded that older players perform a greater number of collective technical-tactical actions (Almeida et al., 2017; Borges et al., 2017; Costa et al., 2010; García et al., 2014; Moreira et al., 2020), while their technical-tactical behaviors and group movement patterns remained unchanged (Barnabé et al., 2016; Brito et al., 2019a; Castellano et al., 2017; Martone et al., 2017; Moreira et al., 2020).

Positional adaptations in training through RGP are not limited solely to improving individual tactics, but also encompass the development of collective understanding and team cohesion. Research by González-Rodenas et al (2025) has shown that training sessions structured around position-specific game scenarios promote better synchronization of movements between players, thus improving collective performance during in-game transitions and defensive phases.

In addition, RGP also promote better communication and understanding between players, which is essential for executing complex strategies and adapting to changing match dynamics. According to a study by Reyes, Lago-Peñas, & Lago-Ballesteros (2023), the improvement in intra-team communication resulting from these specialized training sessions leads to greater tactical efficiency and better resolution of game situations.

This study therefore aims to thoroughly evaluate the impact of such training via RGP in interaction with different playing systems on several soccer performance indicators, to understand how they can be optimized to maximize both individual and collective technical-tactical performance. The aim is to provide coaches with clear guidelines on how to structure their training sessions to meet the technical and tactical demands of contemporary soccer, underlining the importance of personalized and targeted approaches in sports training.

Materials and Methods

The present study aimed to evaluate the impact of training with reduced games involving position play compared to standard training on various soccer performance indicators. The methodology employed is divided into four complementary components, as detailed below.

Study Participants

The sample consisted of 10 teams (07 players per team with goalkeeper) divided into two equal groups belonging to the AMF soccer academy: five experimental teams (positional games training) and five control teams (standard training).

For three months, the experimental teams were trained in two different systems (1-3-2-1 and 1-2-3-1) on a synthetic pitch (58m/34m).

The control teams trained on fields of the same dimensions as the experimental group. Both groups trained 3 times a week, each session lasting 75 minutes.

Players were selected according to inclusion criteria, players aged 16, with an acceptable level of performance and 3 years of competitive experience in the regional league, training 3 sessions and playing one match per week, in accordance with protocols previously described in the literature on soccer performance analysis. Sampling was carried out randomly among teams from recognized clubs, thus guaranteeing comparability between the two groups and controlling for potential confounding variables.

Study Design

The study involved 30 matches between five experimental teams and five control teams. The protocol adopted a mixed factorial design, incorporating both between-subjects and

within-subjects factors. The between-subjects factor “Group” comprises two levels (experimental teams and control teams), while the within-subjects factors “Match” (three successive matches) and “Playing system” (two tactical configurations: 1-3-2-1 system and 1-2-3-1 system) make it possible to examine variations in performance indicators as a function of the playing context. This design, enabling the analysis of interactions between main effects and their combinations, was chosen for its ability to explore several performance dimensions simultaneously (Barbero-Alvarez et al., 2017).

Measurement Instrument

Soccer performance was assessed using an observation grid operated by 4 experts. Thus, indicators collected included ball possession, number of complete and lost passes, number of shots, number of corners, and number of goals scored and conceded (dependent variables). The reliability of the measurements was ensured by repeatability tests and prior training of the analysts, guaranteeing objective and reproducible data collection.

Data Analysis

Data were analyzed using multivariate analysis of variance (MANOVA) to simultaneously test the effect of group (experimental vs. control teams), match and playing

system, as well as their interactions, on all performance indicators (seven dependent variables). Multivariate tests (Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Greatest Root) were performed to assess the homogeneity of main effects and interactions. In addition, univariate analyses detailed the specific contributions of each dependent variable, including reporting the sum of squares, calculated F and partial η^2 as effect measures (Hair et al., 2010; Field, 2018; Tabachnick & Fidell, 2019). Post-hoc comparisons were adjusted using Bonferroni's method to control for type I error rate in multiple testing. All analyses were performed with a significance level set at 0.05.

Results

The multivariate analysis reveals a particularly pronounced main effect of the group (Pillai's Trace = 0.972, $F(7,42) = 206.106$, $p < 0.001$, $\eta^2_p = 0.972$), indicating that small-sided game training (experimental teams) differs globally from standard training (control team) across all performance indicators. The univariate analyses confirm these significant differences for several variables. For instance, ball possession is higher in the experimental teams (mean = 110.70 %) compared to the control team (mean = 89.27 %), representing a relative increase of approximately 24 %. Similarly, the number of completed passes is significantly improved in

Table 1. Means and standard deviations of soccer performance indicators according to the playing system and team group across the three matches. The data are presented as means and standard deviations, derived from the aggregation of the three matches for each combination of playing system and group (n = 15 matches)

Indicator	Team Groups Groups des équipes			
	Experimental Teams (n=5)		Control Teams (n=5)	
	System 1-3-2-1 (3 matches)	Système 1-2-3-1 (3 matches)	System 1-3-2-1 (3 matches)	Système 1-2-3-1 (3 matches)
Ball Possession	110.73 ± 4.86	110.67 ± 6.80	89.00 ± 5.33	89.53 ± 7.32
Completed Passes	119.47 ± 7.51	124.93 ± 4.95	58.73 ± 6.97	60.13 ± 8.10
Lost Passes	25.53 ± 5.04	27.93 ± 5.91	34.93 ± 4.43	34.13 ± 4.47
Shots	6.47 ± 3.66	4.27 ± 2.09	3.47 ± 1.30	3.67 ± 2.19
Corners	4.53 ± 1.36	3.53 ± 1.68	3.93 ± 1.03	3.13 ± 1.64
Goals Scored	2.27 ± 0.88	2.40 ± 0.91	1.47 ± 0.83	1.80 ± 1.01
Goals Conceded	1.47 ± 0.83	1.87 ± 0.99	2.27 ± 0.88	2.40 ± 0.91

Table 2. Multivariate analysis of variance (MANOVA) of the effect of group (experimental teams vs. control teams), match, and playing system, as well as their interactions, on the seven performance indicators

Indicator	Effect			Interactions of Effects			
	Group	PS	Match	G x SJ	G x M	M x SJ	G x M x SJ
Ball Possession	0,000	0,885	0,914	0,107	0,107	0,938	0,312
Completed Passes	0,000	0,063	0,715	0,174	0,174	0,566	0,282
Lost Passes	0,000	0,553	0,360	0,795	0,795	0,728	0,657
Shots	0,008	0,132	0,473	0,556	0,556	0,668	0,464
Corners	0,196	0,022	0,370	0,814	0,814	0,435	0,381
Goals Scored	0,004	0,312	0,013	0,642	0,642	0,670	0,826
Goals Conceded	0,005	0,247	0,014	0,588	0,588	0,757	0,861

Significant at $p < 0.05$, PS. Playing System

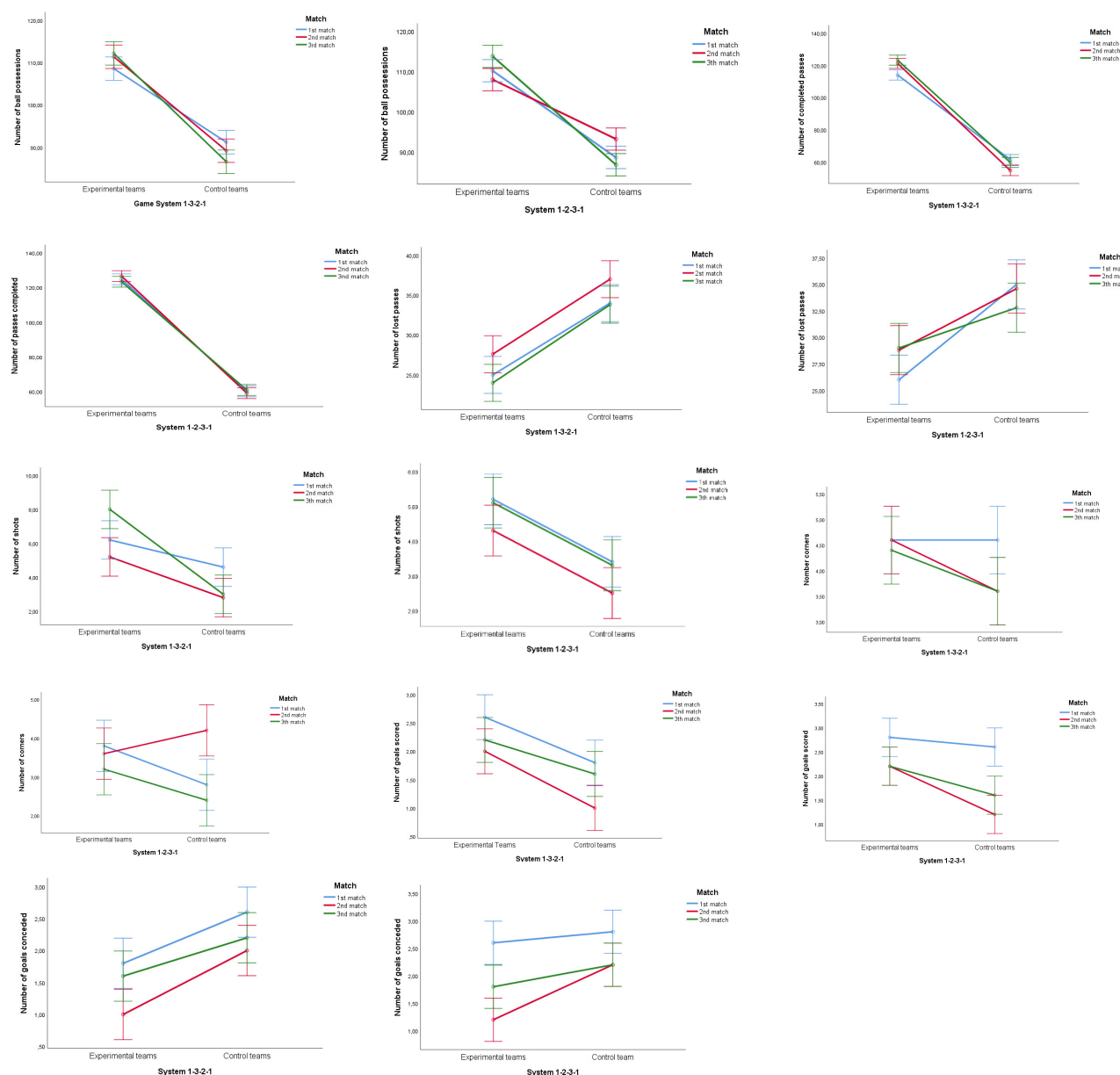


Fig. 1. Variation in game indicator scores for teams undergoing small-sided game training and those following standard training in two playing systems (1-3-2-1; 1-2-3-1)

the experimental teams (mean = 122.20) compared to the control team (mean = 59.43), corresponding to an increase of nearly 106%. Conversely, the number of lost passes decreases significantly by 7.80 units in the experimental teams (mean = 26.73) compared to the control team (mean = 34.53), representing a reduction of approximately 22.6%. Furthermore, the number of shots is significantly higher in the experimental teams (mean = 5.37) than in the control team (mean = 3.57), reflecting an approximate increase of 50%. Moreover, goals scored increase by 0.70 (mean = 2.33 vs. 1.63), representing a relative improvement of approximately 43%, while goals conceded decrease by 0.67 units (mean = 1.67 vs. 2.33), corresponding to a reduction of approximately 29%.

Regarding the effect of the playing system, multivariate tests generally do not reveal a significant influence, with the exception of the “corners” indicator. Univariate analysis

shows that the 1-3-2-1 system (mean = 4.23) produces significantly more corners than the 1-2-3-1 system (mean = 3.33), with a difference of 0.90, representing a relative increase of approximately 27%.

The effect of the match, evaluated over three games, does not show significant variations for most indicators. However, paired comparisons indicate significant differences for goals scored and goals conceded between certain matches. Specifically, the average goals scored is 2.45 in the first match and 1.60 in the second match, a difference of 0.85, which corresponds to a relative variation that can be interpreted either as a decrease of approximately 34.7% or, conversely, as an increase of approximately 53.1% if the value of 1.60 is taken as the reference. A similar pattern is observed for goals conceded, suggesting a comparable change in defensive performance from one match to another.

Finally, the interactions (Group $\times$ Match, Group $\times$ Playing System, Match $\times$ Playing System, and their triple interaction) did not reach the significance threshold, indicating that the impact of small-sided game training on soccer performance is primarily attributable to the effect of the small-sided game training itself and manifests homogeneously regardless of the match or the playing system used.

These results suggest that small-sided game training significantly improves several technical and tactical performance indicators, particularly by increasing ball possession, the number of completed passes, shots, and goals scored, while reducing errors such as lost passes and goals conceded. These observations will be discussed in the following section.

Discussion

The results of this study highlight the significant impact of Reduced games of position (RGP) in interaction with playing systems on soccer performance, particularly in terms of ball possession, passing accuracy, shots, and goals scored. These findings confirm the effectiveness of RGP as a training tool to improve players' technical and tactical skills while enhancing their ability to adapt to different match situations.

One of the most notable results of this study is the significant increase in ball possession among the experimental teams (110.70 %) compared to the control teams (89.27 %). This 24 % improvement suggests that RGP promote better ball control and an enhanced ability to dictate the pace of the game. These results align with the work of Coutinho et al. (2022), who demonstrated that RGP increase the frequency of ball interactions, thereby improving players' ability to maintain possession under pressure. Furthermore, the reduction in lost passes (22.6 %) among the experimental teams indicates that RGP also enhance passing accuracy and decision-making under pressure, a crucial aspect of match performance (Matos et al., 2023).

The number of completed passes increased dramatically in the experimental teams (122.20 compared to 59.43 for the controls), representing a 106 % increase. This improvement can be attributed to the nature of RGP, which require constant communication and quick coordination in confined spaces (Lyons et al., 2021). These conditions simulate real match situations, where players must make quick and precise decisions. Furthermore, the reduction in lost passes (22.6 %) confirms that RGP not only enhance the quantity but also the quality of passes, which is essential for maintaining possession and creating offensive opportunities (Wang et al., 2022).

The experimental teams also showed a significant increase in the number of shots (50 %) and goals scored (43 %). These results suggest that RGP not only improve build-up play but also the ability to finish offensive actions. This improvement may be linked to the repetition of finishing scenarios in realistic game conditions, which reinforces players' confidence and effectiveness in critical areas (Basevitch et al., 2020). Additionally, the reduction in goals conceded (29 %) indicates that RGP also enhance defensive coordination by allowing players to better anticipate defensive transitions and recover the ball more effectively.

Although the main effect of the playing system was not significant for most indicators, a notable exception

was corners. The 1-3-2-1 system generated significantly more corners (27 %) than the 1-2-3-1 system. This could be explained by the more offensive structure of the 1-3-2-1 system, which encourages players to attack wide areas and force defenses to concede corners. These results highlight the importance of adapting playing systems to specific tactical objectives, particularly within the context of SSGs (Clemente et al., 2021; Djaoui, 2017).

The analysis of performance over three consecutive matches revealed significant variations in goals scored and conceded. For example, goals scored decreased by 34.7 % between the first and second match before rising again in the third match. These fluctuations could reflect tactical adjustments or variations in players' physical and mental form during the study period. These results underscore the need to account for performance variability when evaluating the effects of training (Bazvand et al., 2020). In Reduced games with position (RGP), in particular, the demand for ball circulation in terms of speed and amplitude was similar to that of professional matches. Longer possession time does not seem to favor goals scored, according to the results. On the other hand, a higher number of passes has a positive impact on scoring. The data suggest that teams that recover the ball in their defensive zone and string together a large number of passes in a short time increase their chances of scoring (Taha & Ali, 2023). Elements have been found that support the need to use RGP in training, as they provide stimuli similar to those players will encounter in professional settings in the future (Teoldo da Costa & de Freitas Silvino, 2022).

The absence of significant interactions between group, match, and playing system suggests that the benefits of RGP are relatively stable and independent of the game context. This indicates that RGP can be applied flexibly across different playing systems and at different stages of the season while maintaining their effectiveness (Sarmiento et al., 2018).

The results of this study have important implications for coaches. RGP can be used to improve ball possession, passing accuracy, chance creation, and defensive efficiency. Additionally, their flexibility allows them to be integrated into various playing systems, making them a versatile tool for tactical training. However, it is important to note that RGP must be tailored to the specific needs of players and teams, taking into account their skill level and tactical objectives (Hintermann et al., 2021). SSGs can play a significant role in youth and adolescent team sports training, as they develop multidimensional factors (e.g., technical/tactical and physical/physiological factors) (Fernández-Espínola et al., 2020).

This study has some limitations, including the relatively small sample size and the limited duration of the intervention (three months). Future research could explore the long-term effects of RGP on player performance, as well as their impact on other aspects of the game, such as physical conditioning and recovery. Additionally, it would be interesting to investigate the effect of RGP on players of different skill levels to determine whether their benefits are universal or specific to certain groups.

Conclusions

In conclusion, this study demonstrates that Reduced games with position are an effective tool for improving the technical and tactical performance of soccer players.

The results show a significant increase in ball possession, completed passes, shots, and goals scored, as well as a reduction in errors and goals conceded. These benefits are independent of the playing system used, highlighting the versatility of RGP as a training method. These findings offer promising prospects for coaches seeking to optimize team performance while developing the individual skills of their players.

Conflict of Interest

If the authors have any conflicts of interest to declare.

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Оцінювання ефективності редукованих позиційних ігор у футболі: Багатовимірний аналіз техніко-тактичних показників відповідно до різних систем гри

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 8 с., 2 табл., 1 рис., 39 джерел.

Історія питання. Редуковані позиційні ігри (РПІ) розглядаються як визнаний метод тренування для розвитку фізичних, технічних і тактичних якостей юних футболістів. Вони імітують ігрові ситуації реального матчу, заохочуючи до частоті взаємодії з м'ячем та швидкого ухвалення тактичних рішень. Адаптовані до конкретних потреб гравців відповідно до їхньої позиції, РПІ сприяють покращенню рівня фізичної підготовки, ігрового інтелекту та командної згуртованості.

Мета дослідження. Дослідження мало на меті оцінити вплив РПІ на показники техніко-тактичної результативності гравців, порівнюючи їх використання із проведенням стандартних тренувань. Представлена робота спрямована на визначення шляхів оптимізації ключових показників, як-от володіння м'ячем, виконання пасів і ударів, кількість забитих голів та зменшення кількості помилок через використання РПІ, а також вивчення їхнього впливу на тактичну синхронізацію та командну згуртованість.

Матеріали та методи. Дослідження включало проведення 30 матчів між п'ятьма експериментальними та п'ятьма контрольними командами. У протоколі застосовано змішаний факторіальний дизайн, що включає як міжсуб'єктні, так і внутрішньосуб'єктні фактори. Міжсуб'єктний фактор «Група» складається з двох рівнів (експериментальні та контрольні команди), тоді як внутрішньосуб'єктні фактори «Матч» (три послідовні матчі) та «Система гри» (дві тактичні конфігурації: система 1-3-2-1 та система 1-2-3-1) надають можливість дослідити варіації показників результативності як функцію ігрового контексту.

Результати. Результати дослідження продемонстрували, що команди, які тренувалися за методикою РПІ, значно покращили свої показники. Володіння м'ячем збільшилося на 24%, кількість завершених пасів — на 106%, а ударів — на 50%. Крім того, відзначено зростання на 43% кількості забитих м'ячів, тоді як кількість втрачених передач і пропущених м'ячів зменшилася на 22,6% і 29% відповідно. Зазначені переваги не залежать від типу використовуваної системи гри, до того ж спільна редукована позиція покращує комунікацію та синхронізацію між гравцями.

Висновки. РПІ є ефективним тренувальним інструментом для поліпшення показників технічної та тактичної результативності гравців. Застосування вказаного підходу підвищує рівень володіння м'ячем, виконання пасів та ударів, а також кількість забитих голів, водночас зменшуючи кількість помилок і пропущених м'ячів. Отримані результати відкривають широкі перспективи для тренерів, забезпечуючи приведення тренувальних методів у відповідність до вимог сучасного футболу та сприяючи індивідуальному і колективному розвитку гравців.

Ключові слова: редуковані позиційні ігри, система гри, тренування, технічний, тактичний, футбол.

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From Pitch to Console: Exploring the Role of Football eSports in the Development of Young Footballers

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Abstract

Objectives. The study aimed to analyse the impact of football eSports on the perceptions of young footballers, focusing on the key components, namely motivation, technical and tactical skill development, and career choices in the football context.

Materials and methods. Forty-two young footballers playing both traditional football and football videogames took part in the study. Participants were administered an ad hoc questionnaire divided into three sections: sample identification, impact of eSports on aspirations and perspectives, and relationship between digital and traditional practice. Statistical analysis included Fisher's exact test and Chi-square.

Results. The results show that 57.1 % of subjects reported an increase in motivation, especially in adolescence. Furthermore, 73.9 % perceived an improvement in football-related cognitive skills, with a positive influence on actual performance (69 %). Significant relationships were observed between hours spent playing videogames and the perceived enhancement in cognitive skills ($p = .001$), motivation ($p = .032$) as well as the influence on career choices of the latter ($p = .010$).

Conclusions. It is clear from the study that football eSports offer a valuable support to the traditional sporting pathway by stimulating motivation and tactical skills. In addition, this sport of the digital generation can be integrated into the training of young footballers to foster their development and achievement.

Keywords: cognitive skills, football, videogames, questionnaire.

Introduction

The official recognition of eSports by the International Olympic Committee (IOC) on 28 October 2017 marked a major turning point in the global sporting landscape (International Olympic Committee, 2017). Furthermore, the IOC, in cooperation with several international sports federations, organised the first official demonstration event called Olympic Esports Week, held in 2023 in Singapore. This event represented a significant step in the integration of eSports into

the mainstream Olympic context, highlighting the growing recognition of eSports as a structured and regulated form of competition (Hallmann & Giel, 2018). The IOC subsequently announced that the first eSports Olympics will be held in Saudi Arabia in 2025, in line with the growing focus on the development of eSports globally, both as a cultural phenomenon and as an economic opportunity (Taylor, 2012). To this end, the IOC and Saudi Arabia signed a 12-year co-operation agreement, which could act as a catalyst for further development and investment in eSports, not only in the Middle East region but also on an international scale (Jenny et al., 2017). This historic decision opened the door to several virtual competitions involving millions of fans worldwide (Scholz & Barlow, 2019). The eSports represent a cultural and

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sporting revolution that could offer several benefits to young athletes (Sannicandro & Raiola, 2021). Firstly, the practice of eSports requires the development of cognitively loaded motor skills that relate to strategic thinking, decision making, problem solving and hand-eye coordination (Beres & Klarkowski, 2024). Studies conducted by Himmelstein et al. (2017) have shown that professional eSports players possess reaction times like those of traditional elite athletes, highlighting the intense cognitive training required by these sports. These skills not only improve performance in virtual games but can be transferred to other every day and sporting activities that are also cognitively loaded (Giardullo et al., 2024), also increasing understanding of game rules (D'Isanto et al., 2021). Furthermore, eSports promote core values such as discipline, perseverance and teamwork (DiFrancisco-Donoghue et al., 2022). A longitudinal study by Trotter et al. (2020) found that young participants in eSports develop higher levels of self-control and stress management, qualities often neglected in traditional sports. Young athletes participating in eSports competitions often have to train consistently, set goals and work together with their teammates to achieve success (Nagorsky & Wiemeyer, 2020; Raiola, 2015). These training elements are crucial for personal development, helping to create more resilient, resilient and determined individuals (Esposito, 2024; Raiola, 2017). The expansion of eSports has also had a significant impact in terms of inclusiveness and accessibility (Bialecki et al., 2023). Unlike sports, which can require considerable physical and financial resources, eSports offer a growing number of young people the opportunity to compete globally with a relatively modest investment (dos Santos et al., 2018). According to Witkowski (2012), access to eSports represents a cultural revolution, as it allows players from disadvantaged areas to enter world-class competitions, reducing the inequalities present in traditional sports. This democratisation of sport allows talent to emerge regardless of their socio-economic background (Esposito et al., 2020a). Among the most popular and most played videogames are football videogames, which not only evoke the enthusiasm of the crowds in real stadiums but have evolved into a highly technological and competitive form of entertainment and competition, where anyone can reproduce traditional game actions in the virtual environment (Hetrick & Crecelius, 2024). Such videogames not only faithfully recreate the experience of the traditional game but also serve as tools that can enhance the tactical and strategic component of players (Mazza, 2021). Athletes can use these platforms to analyse different game situations, experiment with formations and strategies, and improve their overall view of the field (Esposito et al., 2020b). These videogames can also stimulate interest in playing traditional football (D'Elia, 2023). Many young people, attracted by the virtual game experience, may be inspired to try football on the field, discovering a passion for the sport that may not otherwise have been explored (McNulty et al., 2023). At the same time, in the current context of football practitioners, there is growing uncertainty regarding the choice between the traditional practice of football and the opportunity offered by football eSports. This situation raises questions about the impact that the practice of football eSports may have on the career aspirations, application of technique and tactics, motivation and cognitive abilities of young football practitioners.

Purpose of the research – the present study seeks to investigate the impact of football eSports on the perceptions

of young football players. Specifically, it explores how virtual football practice may influence their motivation, technical and tactical development, and career choices within the sport. By examining these dimensions, the study aims to contribute to a deeper understanding of the intersection between traditional and digital sports practices in youth athlete development.

Materials and Methods

Study Participants

Forty-two football athletes participated in the study, of which 29 males and 13 females, ranging in age from 5 to 19 years. The choice of such a heterogeneous sample was motivated by the desire to investigate how the use of videogames for recreational purposes can influence athletes with different demographic and developmental characteristics, better reflecting the diversity of the young football players population. All participants were involved in football activities, belonging to youth sections of different sports clubs. This variety was considered a strength, as it allows for the exploration of differences and similarities in the approach to videogames in relation to the football context. For younger athletes (5-8 years and 9-12 years), the support of parents or legal guardians was required, both for participation and for understanding the instructions given during the study.

Study Organization

The sampling method used in this study was a convenience sampling strategy, based on the accessibility and availability of participants who were already involved in football activities through various youth clubs. After choosing the target population, data collection was carried out taking into account both the methodological implications and the available economic and human resources. Based on this, it was decided to administer a questionnaire, the drafting of which was based on the conceptual dimensions and related indicators identified during the definition of the research objective and on the outcomes of the specific literature review. An ad hoc questionnaire was developed via Google Forms and sent to the study participants via e-mail and social media. The questionnaire is structured in 15 questions, divided into three parts or sections. The first part of the questionnaire is dedicated to the identification of the sample of participants, gathering information that is fundamental to the context of the study. In the second part, the focus is on analysing the impact of football videogames on young footballers' aspirations and perspectives, exploring how interest in gaming can influence their sporting choices and ambitions. Finally, the third part of the questionnaire focuses on the relationship between football videogames and actual football practice, examining whether and how the experience in digital games can interact with physical activity and traditional competitions. Prior to the main research phase, a pilot phase was conducted with a small group of participants to assess and optimise the clarity and relevance of the questionnaire questions. The feedback gathered during this phase guided targeted changes that led to the final version of the questionnaire. The questionnaire is depicted in Table 1.

All subjects gave their informed consent for inclusion before participating in the study. The study was conducted

Table 1. Questionnaire submitted to athletes

Questions:	Answer 1	Answer 2	Answer 3	Answer 4
1. In what age range do you place yourself?	5-8 years old	9-12 years old	13-16 years old	From 17 years upwards
2. Gender:	Male	Female		
3. How long have you been playing football?	Less than a year	1-3 years	3-6 years	More of 6 years
4. Do you play or have you ever played football videogames (at least once in your life)?	Yes	No		
5. If yes, how much time do you spend, on average, each week on football videogames?	Less than an hour	1-3 hours	3-6 hours	More than 6 hours
6. Do you feel that playing football videogames positively influences your motivation to play football?	For Nothing	A little	Fairly	Very
7. In your opinion, has playing football videogames improved your football-related cognitive skills (e.g. game vision, timing, strategy)?	For Nothing	A little	Fairly	Very
8. Have you ever considered a professional career in football eSports?	Yes	No		
9. What is your main objective in playing football videogames?	For pure enjoyment	To improve my technical skills in traditional football	To improve my tactical skills in traditional football	
10. Do you think playing football videogames can influence your career choices in football?	For Nothing	A little	Fairly	Very
11. What is your overall assessment of the effect of football videogames in youth sports?	Very Negative	Negative	Positive	Very Positive
12. Do your parents limit the time you can spend playing football videogames?	No, not at all	Not very much	Yes, a little	Yes, a lot
13. Do you enjoy playing traditional football or football videogames more?	Traditional football	Football video games	Both equally	
14. Do you think football videogames help you learn new tactics that you can use during traditional matches?	For Nothing	A little	Fairly	Very
15. How important do you think it is to balance time between playing football videogames and exercising?	For Nothing	A little	Fairly	Very

in accordance with the Declaration of Helsinki. According to Regulation (EU) 536/2014 and Directive 2001/20/EC, research that poses minimal risks to participants may be exempt from formal ethical review as it does not involve invasive or experimental interventions. Furthermore, according to Legislative Decree No. 211 of 24 June 2003, research that does not entail significant risks and is aimed solely at improving teaching practices.

Statistical Analysis

To validate the questionnaires, internal consistency was first assessed by means of Cronbach's α coefficient and the corresponding 95 % confidence intervals (CI). A Cronbach's α of 1 indicated perfect reliability, while a threshold value of 0.70 indicated acceptable internal consistency. Subsequently, the descriptive statistics were represented in percentages (%), reflecting the distribution of responses for each of the fifteen questions in the questionnaire. To examine the

relationships between categorical variables and determine their significance, Fisher's exact test was used, chosen for its effectiveness in analysing non-parametric and small sample size data. The analysis was conducted using the Statistical Package for Social Science software (IBM SPSS Statistics for Windows, version 25.0, IBM, SPSS Inc., Armonk, NY, USA).

Results

Once the questionnaire was administered, the answers to it were analysed. This is shown in Table 2.

From the answers given by the sample to the questionnaire, it can be seen that 45.2 % are in the age range 13-16 years, 26.2 % from 17 years upwards, 19 % in the range 9-12 years and finally 9.6 % in the range 5-8 years. Of this sample of athletes, 69 % are male and the remaining 31 % female. To question 3 'How long have you been playing football?' 45.2 % answered more than 6 years, 28.6 % from 1-3 years and the remaining 26.2 % from 3-6 years.

Table 2. Questionnaire responses

Questions:	Answer 1	Answer 2	Answer 3	Answer 4
1. In what age range do you place yourself?	5-8 years old	9-12 years old	13-16 years old	From 17 years upwards
Frequency	4	8	19	11
Percentage	9.6 %	19 %	45.2 %	26.2 %
2. Gender:	Male	Female		
Frequency	29	13		
Percentage	69 %	31 %		
3. How long have you been playing football?	Less than a year	1-3 years	3-6 years	More of 6 years
Frequency	0	12	11	19
Percentage	0	28.6 %	26.2 %	45.2 %
4. Do you play or have you ever played football videogames (at least once in your life)?	Yes	No		
Frequency	42	0		
Percentage	100 %	0		
5. If yes, how much time do you spend, on average, each week on football videogames?	Less than an hour	1-3 hours	3-6 hours	More than 6 hours
Frequency	13	10	14	5
Percentage	31 %	23.8 %	33.3 %	11.9 %
6. Do you feel that playing football videogames positively influences your motivation to play football?	For Nothing	A little	Fairly	Very
Frequency	2	10	24	6
Percentage	4.8 %	23.8 %	57.1 %	14.3 %
7. In your opinion, has playing football videogames improved your football-related cognitive skills (e.g. game vision, timing, strategy)?	For Nothing	A little	Fairly	Very
Frequency	1	10	18	13
Percentage	2.4 %	23.8 %	42.9 %	30.9 %
8. Have you ever considered a professional career in football eSports?	Yes	No		
Frequency	16	26		
Percentage	38.1 %	61.9 %		
9. What is your main objective in playing football videogames?	For pure enjoyment	To improve my technical skills in traditional football	To improve my tactical skills in traditional football	
Frequency	21	6	15	
Percentage	50 %	14.3 %	35.7 %	
10. Do you think playing football videogames can influence your career choices in football?	For Nothing	A little	Fairly	Very
Frequency	8	9	20	5
Percentage	19 %	21.4 %	47.6 %	11.9 %
11. What is your overall assessment of the effect of football videogames in youth sports?	Very Negative	Negative	Positive	Very Positive
Frequency	2	1	26	13
Percentage	4.8 %	2.4 %	61.9 %	30.9 %
12. Do your parents limit the time you can spend playing football videogames?	No, not at all	Not very much	Yes, a little	Yes, a lot
Frequency	17	4	17	4

Table 2 (continued)

Questions:	Answer 1	Answer 2	Answer 3	Answer 4
Percentage	40.5 %	9.5 %	40.5 %	9.5 %
13. Do you enjoy playing traditional football or football videogames more?	traditional football	Football video games	Both equally	
Frequency	21	4	17	
Percentage	50 %	9.5 %	40.5 %	
14. Do you think football videogames help you learn new tactics that you can use during traditional matches?	For Nothing	A little	Fairly	Very
Frequency	1	5	29	7
Percentage	2.4 %	11.9 %	69 %	16.7 %
15. How important do you think it is to balance time between playing football videogames and exercising?	For Nothing	A little	Fairly	Very
Frequency	1	2	8	31
Percentage	2.4 %	4.8 %	19 %	73.8 %

Table 3. Relationship between questions

Questions	p-Value
5. If yes, how much time do you spend, on average, each week on football videogames?	
7. In your opinion, has playing football videogames improved your football-related cognitive skills (e.g. game vision, timing, strategy)?	.001
6. Do you feel that playing football videogames positively influences your motivation to play football?	
5. If yes, how much time do you spend, on average, each week on football videogames?	.032
6. Do you feel that playing football videogames positively influences your motivation to play football?	
10. Do you think playing football videogames can influence your career choices in football?	.010

Continuing with question 4 ‘Do you play or have you ever played football videogames (at least once in your life)?’ It was found that 100 % of the sample responded with yes. Question 5 ‘If yes, how much time do you spend on average, each week on football videogames?’ 33.3 % responded with 3-6 hours, 23.8 % with 1-3 hours, 31 % with less than an hour and the remaining 11.9 % with more than 6 hours. Subsequently to question 6 ‘Do you feel that playing football videogames positively influences your motivation to play football?’ it turns out that 57.1 % responded fairly, 23.8 % with a little, 14.3 % with a lot and the remaining 4.8 % with not at all. In question 7 ‘In your opinion, has playing football videogames improved your football-related cognitive skills (e.g. game vision, timing, strategy)?’ 42.9 % answered fairly, 30.9 % answered very, 23.8 % answered a little and the remaining 2.4 % answered for nothing. In question 8 ‘Have you ever considered a professional career in football eSports?’ 61.9 % answered no, 38.1 % answered yes. Continuing with question 9 ‘What is your main objective in playing football videogames?’ 50 % answered for pure enjoyment, 35.7 % answered to improve my tactical skills in traditional football and the remaining 14.3 % answered to improve my technical skills in traditional football. Question 10 ‘Do you think playing football videogames can influence your career choices in football?’ 47.6 % answered fairly, 21.4 % answered a little, 19 % answered for nothing and the remaining 11.9 % answered a very. Subsequently to question 11 ‘What is your overall assessment of the effect of football videogames in

youth sports?’ 61.9 % responded with positive, 30.9 % with very positive, 4.8 % with very negative and the remaining 2.4 % with negative. In question 12 ‘Do your parents limit the time you can spend playing football videogames?’ for the answers yes a little and no, not at all answered 40.5 % respectively, while for not very much and yes, very much answered 9.5 % for each question mentioned. In question 13 ‘Do you enjoy playing traditional football or football videogames more?’ 50 % responded with traditional football, 40.5 % with both equally, and only 9.5 % with football videogames. In question 14 ‘Do you think football videogames help you learn new tactics that you can use during traditional matches?’ 69 % answered fairly, 16.7 % answered very, 11.9 % answered a little and the remaining 2.4 % answered for nothing. Finally, to question 15 ‘How important do you think it is to balance time between playing football videogames and exercising?’ 73.8 % responded with a lot, 19 % with fairly, 4.8 % with a little and the remaining 2.4 % with for nothing. With Chi-Quadro analysis, several qualitative relationships were found. First, there is a significant relationship between the question 5 ‘If yes, how much time do you spend, on average, each week on football videogames?’ and question 7 ‘In your opinion, has playing football videogames improved your football-related cognitive skills (e.g. game vision, timing, strategy)?’, with a $p = .001$. The second significant relationship found is between question 6 ‘Do you feel that playing football videogames positively influences your motivation to play football?’ and question 5 ‘If yes, how much time do you spend on

average, each week on football videogames?’ with $p = .032$. An additional significant relationship was found between question 6 ‘Do you feel that playing football videogames positively influences your motivation to play football?’ and question 10 ‘Do you think playing football videogames can influence your career choices in football?’ with $P = .010$. This is represented in Table 3.

Discussion

The results show that 100 % of the participants have played football videogames at least once in their lives, with a significant distribution of the time spent playing such games: 33.3 % play for 3-6 hours per week, 23.8 % for 1-3 hours, 31 % for less than an hour and 11.9 % for more than 6 hours. These data reflect the deep integration of videogames in the daily life of young athletes, in line with global trends in contemporary youth culture. Importantly, 57.1 % of the respondents believe that playing football videogames positively influences their motivation to play traditional football. This suggests that videogames can act as a motivational element, providing a complementary experience that enriches interest in traditional football. This phenomenon can be explained through self-determination theory, whereby activities that fulfil the needs for competence, autonomy and relationships can increase intrinsic motivation (Ryan & Deci, 2000). Football videogames, with their dynamics of challenge and progression through levels of difficulty, can satisfy the need for fun, while online communities can satisfy the need for relationships, thus also reinforcing the motivation to play traditional football through the transfer of individual and team tactical skills and decision making. The overall perception of the effect of football videogames in the youth sport context is predominantly positive. However, a small minority expressed negative opinions, indicating a concern about the potentially negative effects of videogames. These countervailing opinions are in line with the literature discussing both the benefits and risks associated with videogames and align with sociometric statistical trends. On the one hand, studies suggest that videogames can improve several cognitive and psychological skills, such as problem solving and hand-eye coordination (Granic et al., 2014). On the other hand, there are concerns about addiction to videogames and the negative impact on psychophysical health, especially if the use of videogames replaces physical activity (Anderson et al., 2017). There is broad recognition of the positive balance between videogaming and sports activity. Videogames can highlight positive football role models, but excessive gaming may lead to addiction, whereas regular physical activity helps counteract sedentary behavior, as noted by Biddle and Asare (2011). The Chi-Square analysis showed a significant relationship between weekly time spent playing football videogames and perceived improvement in football-related cognitive skills with a $p = .001$. This result suggests that the more time young athletes spend playing football videogames, the more they perceive an improvement in their cognitively charged motor skills. Previous studies support this connection, indicating that videogames, particularly action games, can improve specific cognitive skills, such as the ability to process visual information and decision-making (Bavelier et al., 2012). The results of this study align with this evidence, with more

than 70 % of participants perceiving an improvement in their cognitive skills using videogames. These data reinforce the idea that videogames may represent an opportunity to develop skills that are also transferable to the traditional sports context, confirming previous observations that digital games promote strategic thinking and problem-solving. In the context of football games, these skills could translate into a better understanding of game tactics and a greater ability to anticipate the tactical choices of opponents. Another significant relationship is between the perception that football videogames positively influence motivation to play football and the time spent playing football videogames, with a $p = .032$. This suggests that more time spent playing football videogames is associated with a greater perceived increase in motivation to play traditional football, and this finding dispels the common notion that virtual activity harms traditional activity. Engagement in football videogames could strengthen the desire to improve one’s skills in traditional football as well, acting as a bridge between virtual and traditional physical activity. Finally, there is a significant relationship between the perception that football videogames positively influence motivation to play football and the perception that videogames can influence career choices in football, with a $p = .010$. This indicates that participants who believe football videogames increase their motivation are also more likely to believe that such games can influence their career decisions in football. This relationship is particularly relevant in the context of videogames, where increasing professionalization and economic attractiveness may lead young people to consider alternative career paths in eSports. The literature suggests that positive experience in videogames may lead young people to explore professional opportunities in this emerging field (Hamari & Sjöblom, 2017).

Practical Implications

The results of this study offer valuable insights for coaches, educators, and sports clubs involved in youth football. Football videogames appear to support the development of cognitive and motivational aspects related to traditional football, offering a potential tool for engagement, especially among younger or less active athletes. Integrating controlled gaming sessions into sports education programs could enhance tactical awareness and decision-making. Additionally, understanding the dual role of football videogames as both entertainment and skill-enhancement can help clubs develop more holistic training strategies that reflect the evolving interests of digital-native athletes. Moreover, clubs and federations could leverage the positive perception of eSports to promote balanced and structured use of videogames, reinforcing their value as a complementary rather than competitive activity to physical sport. Recognizing eSports as part of the broader sporting culture may also open up new communication channels between clubs and youth players, increasing engagement and retention.

Limitations of the Study

This study presents several limitations that should be acknowledged. Firstly, the relatively small sample size limits the generalizability of the findings. Future studies should include larger and more diverse samples to validate the

observed trends across broader populations. Secondly, the use of a convenience sampling method and the subjective nature of the self-reported data introduce potential biases, such as social desirability or misinterpretation of questions. Another critical limitation is the aggregated analysis of responses, which may overlook important differences between demographic subgroups (e.g., age, gender, football experience). Additionally, the questionnaire relied on participants' self-perception, which may not accurately reflect actual cognitive or motivational outcomes. Finally, varying levels of cognitive and educational development among participants may have influenced their understanding and interpretation of the questions, particularly among the youngest athletes. Further research could incorporate objective measurements of cognitive-motor performance and more detailed subgroup analysis to refine and expand upon these preliminary findings. Expanding the study across different geographic regions and club contexts would also help assess the broader applicability of the insights gained.

Conclusion

The results clearly indicate that football videogames exert a significant influence on aspects such as motivation, development of technical and tactical skills, and career choices, highlighting both opportunities and challenges. The emergence of significant correlations between time spent playing football videogames and perceived improvements in cognitive and motivational skills underlines the potential of these digital tools in supporting the development of skills that are also useful in traditional football. In particular, the game dynamics present in football videogames, such as the simulation of tactical and decision-making situations, offer a unique opportunity to hone skills such as game vision, decision making and responsiveness on the pitch. In light of these findings, it is possible to envisage targeted practical applications, such as the controlled integration of football videogames into youth training programmes, to develop individual and team tactical skills in a simulated environment. A completion of the study could further test the correlation hypothesis between tactical and cognitive skills developed through videogames and their transfer to the field. This could include practical field tests to measure improvement in game vision, quick decision-making and responsiveness in traditional game situations. It is also essential to promote a balanced use of videogames, integrating physical activity and social and cognitive development through practices that balance the benefits of videogames with the potential risks. Educational and training approaches for coaches and young athletes could maximise the benefits of eSports as a complementary tool in sports preparation, helping to build comprehensive and sustainable development paths.

Conflict of Interest

The authors declare that there is no conflict of interest.

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На шляху від футбольного поля до ігрової консолі: Вивчення ролі футбольного кіберспорту в розвитку юних футболістів

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Мета дослідження. Метою дослідження було проаналізувати вплив футбольного кіберспорту на рівень сприйняття юних футболістів, зосередившись на ключових компонентах, а саме: мотивації, розвитку технічних і тактичних навичок та виборі кар'єри у футбольному контексті.

Матеріали та методи. У дослідженні взяли участь 42 юні футболісти, які грають як у традиційний футбол, так і у футбольні відеоігри. Учасникам було запропоновано спеціальний опитувальник (ad hoc questionnaire), розділений на три частини: ідентифікація вибірки, вплив кіберспорту на прагнення та перспективи, а також взаємозв'язок між цифровою та традиційною практикою. Статистичний аналіз включав точний тест Фішера та критерій хі-квадрат.

Результати. Результати показують, що 57,1 % досліджуваних повідомили про підвищення мотивації, особливо у осіб підліткового віку. Крім того, 73,9 % відчули покращення когнітивних навичок, пов'язаних з футболом, що позитивно вплинуло на фактичну результативність (69 %). Спостерігалися значні взаємозв'язки між годинами, проведеними за відеоіграми, та сприйнятим поліпшенням когнітивних навичок ($p = .001$), мотивації ($p = .032$), а також впливом на вибір кар'єри останніх ($p = .010$).

Висновки. Дослідження чітко продемонструвало, що футбольний кіберспорт надає цінну підтримку традиційному спортивному напрямку, стимулюючи мотивацію та тактичні навички. Також цей вид спорту цифрового покоління може бути інтегрований у тренувальний процес юних футболістів з метою сприяння їхньому розвитку та реалізації досягнень.

Ключові слова: когнітивні навички, футбол, відеоігри, опитувальник.

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The Effect of Adapted Physical Activity and Inclusive Sport on the Motivation and Psychological Health of Children with Disabilities: A Randomized Control Trial

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Abstract

Background. Adapted activities have relied on pedagogical, organizational and material adaptations to ensure equitable and beneficial participation for all students.

Objectives. This study aimed to examine the influence of adapted physical education and involvement in school para-athletics on the motivation to engage in sports practice and the psychological well-being of students with motor disabilities.

Materials and methods. The present study involved 96 students with motor disabilities (mean age: 16.79 ± 0.87 years) enrolled in Moroccan public schools. Participants were categorised into three groups based on para-athletics classification: 30 % in class 30, 40 % in classes 40, and 30 % in class 50. Participants were randomly assigned to one of three groups: a control group with no structured intervention, a group following an adapted physical education (APE) programme (24 sessions), and a third group combining the APE programme with additional para-athletics training, including competitions, over a three-month period (24 sessions). The study utilised the SMS-28 scale to measure motivation and Carol Ryff's scale to assess the level of psychological well-being, with evaluations conducted pre- and post-intervention.

Results. The findings indicated that the APE+Para-Athletics group showed notable enhancements in nearly all domains of motivation, including a 205 % increase in intrinsic motivation to stimulation. Additionally, it was observed improvements in psychological well-being, particularly in autonomy and positive relationships with others. In comparison, the control group demonstrated minimal change, while the APE group also recorded improvements, albeit to a lesser extent than the group combining the two programs.

Conclusions. This study confirms that the combination of APE and inclusive sport, including para-athletics, is an effective strategy for optimizing the motivation and psychological well-being of students with motor disabilities.

Keywords: paraspports in schools, psychological health, adapted sports, inclusive education, social relations, personal development.

Introduction

The existing literature demonstrates that the school including of students with disabilities in the educative environment represents a significant challenge for modern education, as it is confronted with a multitude of obstacles (Ballas et al., 2022; Chomistek et al., 2019; Haegele et al.,

2018; Lieberman et al., 2002; Ríos Hernández, 2009; Sammon et al., 2020). One of the most crucial elements of this incorporation is involvement in physical sports activities, which facilitate the student's comprehensive growth and development (Bahadirovna, 2024; Setyawan et al., 2024). The efficacy of adapted activities in enhancing not only physical health but also psychological and social well-being has been demonstrated (Ben Rakaa et al., 2025a; Block & Obrusnikova, 2007). Notwithstanding, students with disabilities frequently encounter significant challenges that

impede their involvement in these activities. Nevertheless, students with disabilities frequently encounter substantial obstacles that restrict their involvement in inclusive activities (Ben Rakaa et al., 2024c). The aforementioned barriers may be classified as either physical, structural, or behavioral. This underscores the necessity for the implementation of suitable educational strategies to overcome these barriers (Direction des Curricula, 2019a, 2019b, 2019c; Goodwin & Watkinson, 2000). The findings of a prior investigation yielded indisputable evidence of the correlation between personality characteristics and academic performance, establishing a pivotal connection of considerable significance (Alderotti et al., 2023). She emphasized the necessity of considering the psychological dimension in order to more accurately comprehend student conduct and to furnish them with suitable psychological assistance (Bouiri et al., 2021). Subsequently, affective, cognitive, and metacognitive learning strategies have been demonstrated to be effective with respect to academic outcomes, as they engender constructive academic results (Bouiri et al., 2021). Subsequently, affective, cognitive, and metacognitive learning strategies have been demonstrated to be effective in enhancing academic performance, as they facilitate the generation of constructive academic outcomes (Bouiri et al., 2021). These learning strategies assist in elucidating the subtleties of learners' mental processes. It thus appears imperative to intensify our endeavors to enhance the efficacy and applicability of educators' pedagogical interventions (Bouiri et al., 2021). In this sense, adapted physical education (APE) and school-based para-sport can be effective instruments for encouraging regular physical exercise and intrinsic motivation towards physical activity in these students (Shields & Synnot, 2016).

The extant literature indicates that APE have a significant impact on student motivation, particularly by enhancing their sense of competence and facilitating constructive learning experiences (Montilla et al., 2023; Vazou et al., 2005). Moreover, involvement in para-athletic pursuits at the educational level can be instrumental in fostering not only competitive physical activity, but also a constructive sporting identity in students with disabilities (Hutzler, 2011). Nevertheless, in the pursuit of a more profound exploration into the effects of APE and para-athletics on the motivation of pupils with motor disabilities, it is essential to conduct a thorough examination of the specific context in which these interventions are implemented. The motivation to engage in physical activity and the psychological well-being of pupils with disabilities are shaped by a complex interplay of influences. These encompass both individual factors, such as expectations of achievement and feelings of competence, and contextual elements, including the availability of teacher and peer support, as well as the accessibility of sports facilities (Deci & Ryan, 2000). In the specific context of students with motor disabilities, motivation to engage in physical activity is significantly influenced by the quality of the educational intervention and the availability of inclusive physical activity opportunities. Recent research findings have indicated that participation in the APA programme has the potential to enhance various domains of functioning, including physical capacities (Lourenço et al., 2025), self-esteem, and overall well-being (Ben Rakaa et al., 2025b; Wickman et al., 2018). Adapted pedagogical interventions play an

instrumental role in fostering a secure and encouraging learning atmosphere (Belabbès et al., 2025; Ben Rakaa et al., 2025a), wherein students can nurture their motor abilities at a pace that aligns with their unique capabilities (Healy et al., 2013). Furthermore, involvement in para-sport provides students with motor disabilities with the chance to engage in structured sporting events, which can enhance their sense of efficacy and autonomy (Alexander, 2023).

A study has demonstrated that participation in adapted competitive sports not only facilitates improvement in students' physical fitness (Lourenço et al., 2025), but also fosters a sense of achievement and reinforces intrinsic motivation to engage in regular physical activity (Orr et al., 2021). Conversely, the integration of APE and involvement in para-sport, including para-athletics, para-swimming, amputee soccer, and so forth, within the school environment represents a promising strategy for motivating pupils with motor disabilities to engage in physical exercise (Vazou et al., 2005). The integration of these two elements in a coherent and sustainable manner has the potential to encourage greater participation of students with disabilities in sport, as much as facilitating their personal and social development by offering them significant opportunities for success and inclusion (Hutzler, 2011; Vazou et al., 2005). In light of the difficulties encountered when inclusion learnings with impairments into APE programs and promoting their involvement in school-based para-sports, particularly para-athletics, a potential solution could be to combine these two approaches in order to foster motivation for exercise in these children with motor disabilities. It is therefore essential to evaluate the effectiveness of APE programs and para-athletics in this context. This perspective gives rise to a key question: what is the impact of para-athletics and APE on the motivation and psychological well-being of learnings with motor disabilities to engage in PE? This research aims to ascertain the impact of APE and participation in school para-athletics on motivation to take part in sport activities and the well-being of pupils with motor disabilities.

Materials and Methods

Study Design and Participants

The research included 96 participants with motor disabilities, aged 16.79 ± 0.87 years, enrolled in mainstream public schools across various regional academies in Morocco. Among them, 35% resided in rural areas, while 65% lived in urban settings. The selection criteria encompassed enrolment in a general education classroom alongside able-bodied peers, possession of a disability certificate issued by Entraide Nationale, and a medical certificate confirming their physical ability to participate in physical education courses. Written informed consent was obtained from parents or legal guardians for both participation in the study and publication of its findings.

Before inclusion, participants underwent classification according to the International Paralympic Committee's disability system, assessed by volunteer experts in the field (International Paralympic Committee, 2016). The classification results indicated that 40% qualified for field events (throwing disciplines), while 60% were eligible for track events (running and/or jumping). Within the track-

eligible group, 30% had cerebral disabilities, 40% had limb amputations or similar conditions, and 30% had motor impairments resulting from spinal cord injuries.

This randomized controlled trial (RCT) evaluated the efficacy of two adapted programmes: an APE program and a combined APE+Para-athletics program. Participants were stratified into three groups: Control: No structured APA engagement. APE: Two 1-hour weekly APE sessions for three months, focusing on skill development in throwing and running/jumping within pedagogical cycles. APE+Para-athletics: APE sessions plus two supplemental 1.5-hour weekly Para-athletics trainings, emphasizing performance optimization and participation in multi-level inclusive school competitions (provincial to national).

Program Structure : The school-based APA curriculum targeted motor disabilities (e.g., cerebral palsy, amputations, spinal cord injuries) to enhance physical engagement in PE and phased integration into competitive sports. PE teachers designed ability-tailored APE learning cycles aligned with students' needs, followed by Para-athletic training protocols to prepare students for inclusive competitions. The intervention followed three progressive phases—initiation (foundational skill acquisition), development (technical refinement), and consolidation (performance application)—with intensity calibrated to individual abilities. Session content was dynamically adjusted via biweekly assessments and individualized progress tracking. Inclusive competition participation was embedded to foster physical and social growth. Pre- and post-test evaluations included the OMSAT-4 sport competency assessment, Sense of Pedagogical Inclusion Scale, and Sense of School Inclusion Scale (SSI).

Research Instruments

Psychological well-being: The Ryff Psychological Well-Being Scale is a multidimensional tool designed to assess six key aspects of well-being: autonomy, environmental mastery, personal growth, positive relationships, purpose in life, and self-acceptance. Developed in 1989, it utilises a Likert scale to measure these dimensions. This instrument is widely used to evaluate psychological well-being across diverse cultural and clinical settings (Ryff, 1989).

Motivation to practice sports: The Sport Motivation Scale (EMS-28) is a tool designed to assess the degree of intrinsic and extrinsic motivation of individuals to engage in sporting activities. The scale assesses seven concepts, including intrinsic motivation for accomplishment, knowledge, and stimulation; external, introjected, and identified regulation; and amotivation. The scale consists of 28 items in total, with four items representing each of the seven subscales. Participants are requested to indicate their degree of agreement with each statement on a scale of 1 to 7 points (Brière et al., 1995).

Data Analysis

A descriptive analysis was performed for all the examined variables, after which a one-way ANOVA was applied to assess differences between the pre- and post-test results concerning motivation types and well-being. When statistically significant differences were identified, the percentage variation was

computed using the following formula: $(\text{Post-Test} - \text{Pre-Test}) / \text{Pre-Test} * 100$. To further analyse the impact of each variable pair within the three groups (control, APE, and APE + para-athletics), a Bonferroni-adjusted repeated-measures ANOVA was conducted. Finally, Pearson's correlation test was employed to determine the strength of associations among the studied variables.

Results

This section employs a three-tiered analysis. Initially, it provides a detailed description of the descriptive statistics, including the mean and standard deviation of various psychological motivation and well-being indicators, recorded prior to and following the experimental protocol. Subsequently, it examines the differences among the three study cohorts at both the pre- and post-intervention stages. Finally, it explores the correlations between the assessed skills.

Comparison of Pre- and Post-Test Psychological Variables

Table 1 presents a comparison of the effects of distinct interventions on various forms of motivation and psychological well-being across three groups: a control group, a group engaged in an adapted physical education program (APE), and a group combining APE and para-athletics practice. For the control group, the results indicate minimal notable changes in the observed variables. Indeed, the majority of variables associated with intrinsic and extrinsic motivation did not exhibit a significant alteration following the intervention.

The APE program resulted in notable enhancements across multiple domains of motivation and psychological well-being. For example, there was a notable increase in intrinsic motivation accomplishment (+30.71%, $p < .000$), as well as external regulation (+23.907%). Furthermore, participants exhibited a notable enhancement in psychological well-being, with an increase in personal growth from 2.81 to 4.42 ($p = .002$) and a significant rise in positive relationships with others (+4.077%).

The group that participated in the APE, with the inclusion of Para-Athletics, demonstrated remarkable increases in nearly all of the variables that were measured. There was an impressive 205.044% increase in intrinsic motivation to stimulation, while external regulation increased by 180.63%. These findings indicate a significant progression in both dimensions of motivation. With regard to psychological well-being, this group also exhibited noteworthy improvements, including enhanced autonomy (+7.646, $p < .000$) and positive relationships with others (+7.501).

Measuring the Impact of Experimental Protocols on Psychological Variables Such as Motivation and Well-Being

Tables 2 and 3 present the findings of a repeated-measures analysis of variance (ANOVA) investigating the influence of diverse intervention modalities on psychological variables, including motivation and well-being. The results indicate that all the variables examined show significant differences between groups, with F values ranging from 7.804 for self-acceptance to 138.682 for intrinsic motivation towards knowledge. In all cases, the

Table 1. Development of motivation and psychological well-being before and after intervention

Variables	Experimentation											
	Control				APE							
	Avant	Après	F	P	Avant	Après	F	P	APE+ ParaAthletics			
Knowledge	2.69±0.39	3.06±0.74	3.960	NS	3.26±0.80	4.43±0.86	34.046	.000	3.48±1.10	6.15±0.79	132.224	.000
Accomplishment	2.82±0.54	3.01±0.69	2.136	NS	3.29±0.90	4.34±0.73	30.711	.000	3.54±1.19	6.34±0.61	122.739	.000
Stimulation	2.95±0.70	2.95±0.74	0.026	NS	3.37±1.11	4.35±0.96	14.679	.000	3.30±0.93	6.40±0.66	205.044	.000
Identified regulation	2.92±0.71	2.97±0.74	0.256	NS	3.64±1.35	4.44±1.16	5.625	.021	3.64±0.76	6.55±0.60	233.586	.000
Introjected regulation	2.87±0.68	2.98±0.66	0.428	NS	3.48±1.18	4.40±0.83	14.649	.000	3.58±0.82	6.47±0.75	183.455	.000
External regulation	2.90±0.72	3.03±0.70	0.357	NS	3.38±1.05	4.54±0.83	23.907	.000	3.46±0.76	6.31±0.83	180.630	.000
Amotivation	2.91±0.85	2.98±0.87	0.000	NS	3.31±0.93	4.43±0.77	19.258	.000	3.63±0.94	6.42±0.72	167.111	.000
Autonomy	2.18±1.40	2.18±1.40	0.000	NS	4.16±1.44	5.39±1.84	-2.775	.009	4.16±1.74	6.50±0.76	-7.646	.000
Environmental mastery	2.88±1.49	2.76±1.54	0.318	NS	3.45±1.52	5.42±1.96	-4.151	.000	3.72±1.53	6.31±0.78	-8.824	.000
Personal growth	2.27±1.26	2.52±1.25	-0.713	NS	2.81±1.64	4.42±2.00	-3.432	.002	3.03±1.75	5.34±1.45	-6.136	.000
Positive relations with others	2.48±1.52	2.21±1.27	0.727	NS	2.84±1.63	4.74±2.02	-4.077	.000	3.28±1.82	5.91±1.23	-7.501	.000
Purpose in life	2.73±1.86	2.48±1.44	0.643	NS	2.94±1.93	5.90±1.68	-7.178	.000	3.47±1.87	6.28±1.37	-6.378	.000
Self-acceptance	2.39±1.68	2.88±1.58	-1.174	NS	2.61±1.73	4.26±2.28	-3.437	.002	2.78±1.62	5.13±1.98	-5.850	.000

All results are written as mean±standard deviation, Significant $p < .05$, NS. Not significant

Table 2. Effect of protocol on motivation and psychological well-being variables

Variables	SC	df	Mean square	F	p
Knowledge	122.568	2	61.284	138.682	
Accomplishment	133.683	2	66.842	121.18	
Stimulation	117.464	2	58.732	104.013	
Identified regulation	150.909	2	75.454	108.594	
Introjected regulation	144.177	2	72.088	111.184	
External regulation	119.978	2	59.989	98.04	
Amotivation	140.106	2	70.053	88.278	.000
Autonomy	367.354	2	183.677	85.724	
Environmental mastery	168.935	2	84.467	39.269	
Personal growth	109.262	2	54.631	22.36	
Positive relations with others	168.553	2	84.277	32.563	
Purpose in life	187.625	2	93.812	30.204	
Self-acceptance	57.293	2	28.646	7.804	

SC. Somme des carrés de Type III, M. Motivation, BE-P. Bien-Etre Psychologie, Significative $p < .05$

observed differences were statistically significant at the 0.05 level. The most pronounced differences were observed in intrinsic motivation for knowledge ($F = 138.682$, $p = 0.000$) and intrinsic motivation for accomplishment ($F = 121.18$, $p = 0.000$), while the smallest differences concerned self-acceptance ($F = 7.804$, $p = 0.001$). Table 3 demonstrated that there were also notable differences between the groups ($p < .05$) for the majority of the parameters examined, particularly for all dimensions of motivation, intrinsic and extrinsic, as well as for amotivation. However, some measures of psychological well-being, such as autonomy, environmental mastery and purpose in life, exhibited non-

significant (NS) differences between select pairs of groups, notably between APE and APE + Para-Athletics.

Relationship between Psychological Variables Such as Motivation and Well-Being

Table 4 illustrates the correlations between the various motivational variables and those pertaining to psychological well-being. The results demonstrate robust and highly significant correlations between the various dimensions of motivation, with coefficients reaching 0.966 between extrinsic motivation (external regulation) and amotivation.

Table 3. Pairwise comparison of psychological variables

Variables	Control		APE		APE+ ParaAthletics	
	APE	APE+ ParaAthletics	Contrôle	APE+ ParaAthletics	EPA	Contrôle
Knowledge	.000	.000	.000	.000	.000	.000
Accomplishment	.000	.000	.000	.000	.000	.000
Stimulation	.000	.000	.000	.000	.000	.000
Identified regulation	.000	.000	.000	.000	.000	.000
Introjected regulation	.000	.000	.000	.000	.000	.000
External regulation	.000	.000	.000	.000	.000	.000
Amotivation	.000	.000	.000	.000	.000	.000
Autonomy	.000	.000	.000	NS	.000	.000
Environmental mastery	.000	.000	.000	NS	.000	.000
Personal growth	.000	.000	.000	NS	.000	.019
Positive relations with others	.000	.000	.000	.019	.000	.000
Purpose in life	.000	.000	.000	NS	.000	.001
Self-acceptance	.000	.001	NS	.000	.001	.000

Significative $p < .05$, NS. Non Significant**Table 4.** Correlation between types of motivation and well-being

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Knowledge	1												
2. Accomplishment	.951**	1											
3. Stimulation	.895**	.953**	1										
4. Identified regulation	.839**	.899**	.952**	1									
5. Introjected regulation	.846**	.896**	.924**	.957**	1								
6. External regulation	.853**	.857**	.877**	.914**	.963**	1							
7. Amotivation	.838**	.869**	.863**	.891**	.944**	.966**	1						
8. Autonomy	.634**	.688**	.721**	.747**	.711**	.693**	.673**	1					
9. Environmental mastery	.564**	.605**	.642**	.688**	.657**	.655**	.638**	.833**	1				
10. Personal growth	.478**	.484**	.531**	.587**	.569**	.601**	.554**	.565**	.565**	1			
11. Positive relations with others	.685**	.657**	.682**	.690**	.683**	.734**	.708**	.659**	.587**	.626**	1		
12. Purpose in life	.567**	.588**	.613**	.630**	.620**	.605**	.575**	.672**	.636**	.498**	.532**	1	
13. Self-acceptance	.386**	.382**	.410**	.417**	.418**	.454**	.443**	.383**	.253*	.476**	.419**	.244*	1

** Très Significative ($p < .01$), * Significative ($p < .05$)

With regard to psychological well-being, although the observed correlations are generally weaker than those observed for motivation, some remain highly significant. For example, a correlation of 0.833 was observed between autonomy and environmental mastery. Conversely, the lowest correlation was observed between self-acceptance and environmental mastery (0.253). These findings suggest strong interconnections between the different facets of motivation and variable links with dimensions of psychological well-being.

Discussion

The findings of this study reinforce the substantial impact of adapted physical education (APE) and school para-

athletics on the motivation to engage in sporting activities and on the psychological well-being of young people with motor disabilities. APE has been demonstrated to be an efficacious intervention for enhancing intrinsic motivation in pupils, as it facilitates long-term dedication to physical activity. This increase in intrinsic motivation was particularly pronounced in dimensions linked to knowledge, accomplishment, and stimulation, underscoring the importance of an educational framework that meets the specific needs of students in terms of inclusion and learning (Wickman et al., 2018). However, the assessment of motor impairments should be initiated at an early age. Research findings indicate that children who are subsequently identified as having higher mastery motivation demonstrate superior developmental outcomes in multiple domains, including cognition, problem-solving, language

and fine motor skills, when compared to their peers who exhibit lower mastery motivation (Babik et al., 2024).

Conversely, intrinsic motivation for stimulation demonstrated a more pronounced enhancement, as it reflects the interest and enjoyment that students derive from engaging in physical activity for its intrinsic value, without any anticipation of external rewards (Zheng et al., 2023). These findings align with the tenets of self-determination theory, which posits that the fulfillment of psychological needs for competence, autonomy, and relationships fosters autonomous and enduring motivation (Ryan & Deci, 2017). The APE approach for students with disabilities is tailored to the specific capabilities of each individual, allowing them to engage in the exploration and development of their motor skills at a pace that is appropriate for them (Zamiri & Esmaeili, 2024). This approach has been demonstrated to enhance motivation to persist in participation in physical activities (Healy et al., 2013). A further study has demonstrated a notable disparity in the involvement of students with disabilities in physical sports activities (Ben Rakaa et al., 2024b). Furthermore, the perceptions and feelings of pedagogical competence among physical education teachers with regard to the management of these students have a considerable impact on their inclusion in the classroom (Ben Rakaa et al., 2024c, 2024a).

In addition to APE, participation in a school para-athletics program was found to have a significant synergistic effect on students' motivation and psychological well-being. Students who participated in the combined APE and para-athletics program reported increases in various forms of motivation and essential dimensions of psychological well-being, including autonomy, environmental mastery, and purpose in life. The findings of this study corroborate those of previous research, which indicate that participation in para-athletic competitions has a positive effect on students' sense of competence and achievement (Liska et al., 2024; Martin, 2013). This finding is consistent with the existing literature on the positive effects of structured sports activities on self-esteem and general well-being (Liska et al., 2024; Martin, 2013).

Nevertheless, the implementation of an inclusive leadership approach necessitates collaboration within educational institutions, the empowerment of employees through consistent guidance and support, the fortitude to alter established practices, and an inclination to gain knowledge about diversity and cultural dissimilarities (Okun, 2023). Furthermore, participation in sporting events provides students with invaluable opportunities for constructive social interaction, which has a significant influence on the formation of their identity and self-image (Zhang & Qin, 2023). These interactions are frequently regarded as instances of social recognition, during which students can not only exhibit their capabilities but also receive encouragement and commendation from their peers and instructors (Shields & Synnot, 2016). The social reinforcement that these athletes receive has a considerable and enduring effect on their motivation to engage in sporting activities and on the development of a positive sporting identity (Vazou et al., 2005).

The analysis of the correlations between motivational variables and psychological well-being in the study revealed significant relationships that underscore the interdependence of these dimensions. For example, the findings illustrate

a robust correlation between intrinsic motivation for knowledge and autonomy, indicating that students driven by the aspiration to learn and master new competencies are also those who exhibit the most pronounced sense of autonomy within their academic context (Deci & Ryan, 2000). The perception of autonomy has been shown to foster a sense of control over one's actions and decisions, which in turn maintains a high level of intrinsic motivation over the long term (Ryan & Deci, 2017).

Moreover, the significant correlations between environmental mastery and other dimensions of psychological well-being, such as personal development and positive relationships with others, indicate that students who perceive control over their environment are also those who demonstrate indications of personal development and social well-being (Kleinkorres et al., 2023). These findings align with the theoretical proposition that perceived environmental mastery is a significant predictor of psychological well-being (Healy et al., 2013). Moreover, the substantial correlation between extrinsic motivation and amotivation indicates that when students are predominantly driven by external factors, they may be more susceptible to a decline in their overall motivation. This underscores the necessity to cultivate more autonomous forms of motivation (Vazou et al., 2005).

Notwithstanding, certain dimensions of psychological well-being, such as self-acceptance, did not exhibit such pronounced disparities between groups. This result indicates that self-acceptance, as a more complex aspect of psychological well-being, requires more targeted and potentially longer-term interventions to exert a significant influence (Kraiss et al., 2022; Ryff, 1989). It seems reasonable to posit that external factors, such as family support or social experiences outside the university setting, exert a more pronounced influence on the improvement of this specific aspect of psychological well-being (Douwes et al., 2023). These findings suggest that while the APE and para-athletics have beneficial effects on motivation and dimensions of well-being, a more comprehensive approach is necessary to address the full range of psychological well-being in students with disabilities (Shields & Synnot, 2016). The level of well-being of individuals with a physical disability was significantly higher than that of individuals with a hearing disability (Ayyildiz et al., 2024; Ben Rakaa et al., 2025b).

These individuals demonstrate a high level of self-control and utilize a range of coping strategies that facilitate their success in their respective roles (Sun et al., 2024). As the level of education of people with disabilities increases, they are better able to comprehend the relationship between physical activity and health. This enables them to participate in sports at a higher level, which in turn helps to prevent a decline in their external physical motivation as they age. However, there is a need to provide a more detailed explanation of the positive effects of high levels of physical activity, particularly in later life (Ayyildiz et al., 2024). The efficacy of interventions such as APE and para-athletics is contingent upon a multitude of contextual variables, including the level of education, the accessibility of resources, and the level of support from peers and educators (Goodwin & Watkinson, 2000). Therefore, to optimize the impact of these programs, it is imperative to develop individualized approaches that take into account the specific needs of each student (Deci & Ryan, 2000; Wickman et al., 2018).

The personalization of interventions has the potential to enhance student engagement, facilitate greater social inclusion, and promote a more comprehensive approach to personal development (Zurbriggen et al., 2023). In addition to the findings of this study, it is evident that APE and school para-athletics have a beneficial effect on the motivation and psychological well-being of students with motor impairments. The results lend support to the notion that these interventions should be systematically integrated into school programs, thereby maximizing their effectiveness and fostering the inclusion and personal development of these students (Zurbriggen et al., 2023). Further research should concentrate on identifying the underlying mechanisms of these effects and developing strategies to enhance aspects of psychological well-being that have not been significantly influenced by these interventions.

Conclusion

The present study's findings emphasise the considerable impact of APE and school-based para-athletics on the motivation and psychological well-being of learners with motor disabilities. It is noteworthy that interventions integrating both adapted physical education and para-athletics yielded the most substantial enhancements, particularly in cultivating intrinsic and extrinsic motivation alongside diverse facets of psychological well-being. The enhancement in motivation driven by stimulation and life purpose, coupled with strengthened positive social interactions, emphasises the crucial role of these programmes in supporting students' personal and social growth.

The findings of this study have significant practical implications for educators and policymakers. The systematic integration of environmental education and para-athletics into school curricula has the potential to enhance the motivation of pupils with motor disabilities to engage in sporting activities, while simultaneously facilitating their social inclusion and personal development. It is recommended that schools cultivate collaborative relationships with local sports associations to facilitate regular participation in para-athletic activities. Conversely, the less pronounced results with regard to self-acceptance suggest that more targeted and sustained interventions may be required to exert a favorable influence on this aspect of well-being.

Future research should examine the impact of additional variables, such as parental support and access to sports facilities outside the school setting, on the motivation and well-being of disabled pupils. Furthermore, longitudinal studies would enable the evaluation of the long-term sustainability of the observed effects and enhance our comprehension of the long-term impact of these interventions on the developmental trajectories of these pupils. Such research would assist in the refinement of inclusion strategies within educational systems.

Conflict of Interest

All authors declare no conflict of interest.

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Вплив адаптованої фізичної активності та інклюзивного спорту на мотивацію та психологічне здоров'я дітей з інвалідністю: Рандомізоване контрольоване дослідження

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 10 с., 4 табл., 49 джерел.

Історія питання. Адаптовані види активності спираються на педагогічні, організаційні та матеріальні адаптації для забезпечення рівноправного та корисного залучення всіх учнів.

Мета дослідження. Це дослідження мало на меті вивчити вплив адаптованого фізичного виховання та залученості до шкільної параатлетики на мотивацію до спортивної практики та психологічне благополуччя учнів з порушеннями рухових функцій.

Матеріали та методи. У представленому дослідженні взяли участь 96 учнів з порушеннями розвитку моторних функцій (середній вік: 16,79 ± 0,87 років), які навчаються в марокканських державних школах. Учасників було розподілено на три групи відповідно до параатлетичної класифікації: 30 % у класі 30, 40 % у класах 40 та 30 % у класі 50. Досліджуваних було рандомізовано в одну з трьох груп: контрольну групу без структурованої інтервенції, групу, яка займалася за програмою адаптованого фізичного виховання (АФВ) (24 заняття), і третю групу, яка поєднувала програму АФВ з додатковими тренуваннями з параатлетики, включаючи змагання, впродовж тримісячного періоду (24 заняття). У дослідженні використовувалася шкала вимірювання спортивної мотивації SMS-28 (The Sport Motivation Scale) та шкала для оцінки рівня психологічного благополуччя за методикою Керол Ріфф (Carol Ryff's scale of Psychological Well-being), причому оцінювання показників проводилося на перед- та постінтервенційному етапах дослідження.

Результати. Результати дослідження свідчать про те, що група учасників програми, у якій застосовувалась методика АФВ та тренування з параатлетики продемонструвала помітне поліпшення показників майже у всіх аспектах мотивації, включаючи 205 % зростання внутрішньої мотивації до стимулювання. Крім того, спостерігалось покращення психологічного благополуччя, зокрема, самостійності та позитивних стосунків з оточуючими. Для порівняння, контрольна група продемонструвала мінімальні зміни, тоді як у групі АФВ також було відзначено поліпшення показників, хоча й меншою мірою, ніж у групі, що поєднувала обидві програми.

Висновки. Це дослідження підтверджує, що поєднання АФВ та інклюзивного спорту, зокрема параатлетики, є ефективною стратегією щодо оптимізації мотивації та психологічного благополуччя учнів з порушеннями рухових функцій.

Ключові слова: параспорт у школах, психологічне здоров'я, адаптовані види спорту, інклюзивна освіта, соціальні відносини, особистісний розвиток.

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Anthropometric Characteristics of Young Bocce Athletes in the Raffa Specialty: An Analysis of Physical Parameters in Junior Players of National Level

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Abstract

Background. The sport of bocce, and in particular the specialty of Raffa, has seen significant competitive development in recent decades, but the scientific literature on the anthropometric characteristics of athletes, especially among young people, is still limited.

Objectives. This study aimed to analyze the physical characteristics of Raffa's junior players at national level, focusing on anthropometric variables such as height, weight and body mass index (BMI).

Materials and methods. A sample of twenty athletes, divided into a research group consisting of ten athletes of national interest and a control group of ten non-competitive practitioners, was subjected to baseline measurements during regional events.

Results. The findings showed an average height of 170.5 cm and an average weight of 65.8 kg for the research team, with an average BMI of 22.63, indicating a condition of normal weight. However, 33.3 % of the athletes in the research group were overweight or class I obese, suggesting the need for greater attention to physical preparation. The data were compared with those of the control group, which had an average height of 173.5 cm, an average weight of 74.5 kg and a BMI distribution with 50% of the athletes classified as overweight. The results were discussed in relation to the initial hypotheses and the existing literature.

Conclusions. This study offers important insights for the development of personalized training programs and for the selection of young talents, highlighting the importance of adequate physical preparation. Future prospects include deepening the analysis of the somatotype and the use of larger and more diverse samples.

Keywords: anthropometry, sport, training, athletes, physical performance.

Introduction

The sport of Bocce, and in particular the Raffa discipline, is a game rooted in centuries-old tradition, yet it has undergone significant technical, tactical, and physical evolution over the past few decades (Febrianingrum, & Diana, 2021). Once regarded primarily as a recreational activity, Raffa is now played at highly competitive levels, requiring athletes not only to possess technical skills and mental focus, but also a solid physical preparation and appropriate morpho-functional characteristics (Şimşek & Kesilmiş, 2022). In this context, the analysis of anthropometric features in young athletes is gaining

increasing importance, particularly in areas such as athlete selection, training, and talent prediction. Anthropometry, the study of the measurements and proportions of the human body, represents a fundamental component in evaluating the morphological suitability of an athlete in relation to the specific demands of their sport (Gür et al., 2022). Numerous scientific studies have demonstrated the significance of certain body characteristics in predicting athletic success, with clear specificity depending on the discipline. While sports like basketball or volleyball favor taller athletes with long limbs, disciplines such as artistic gymnastics or diving benefit from more compact and lighter physiques. However, in the case of Raffa, scientific literature remains scarce regarding the analysis of ideal anthropometric components, especially among young athletes (Yuan & Li, 2022; Geçitli et al., 2021). The Juniores category in Raffa marks a crucial

phase in the athletic development of players: it is during this stage that they transition from basic sports practice to a more structured and performance-oriented approach (Türkmen et al., 2018). Consequently, understanding which physical traits are most advantageous can offer valuable tools not only for coaches and trainers in making more targeted selections, but also for the athletes themselves, allowing them to adjust their training according to their strengths and areas needing improvement. Raffa differs from other bocce specialties (such as Volo or Petanque) through a series of technical and regulatory elements that require particular abilities in coordination, precision, postural stability, as well as strength in the dominant arm and core muscles. Moreover, contrary to common assumptions, this discipline involves a substantial amount of repetitive movements, torso rotations, and weight transfers, factors that engage various body segments, suggesting a potential relevance of anthropometric proportions (Eler & Eler, 2018). Studies in the broader sports science field have highlighted the importance of parameters such as height, body weight, body mass index (BMI), limb length, wrist and arm circumference, and body composition (percentage of lean and fat mass) in determining athletic performance (Yuan & Li, 2022).

Despite the long tradition of bocce and growing interest in its development among young and competitive athletes, scientific literature specifically focused on the Raffa discipline remains extremely limited. Most studies in the sports field concentrate on disciplines that are more widespread and well-structured in terms of research, such as football, athletics, gymnastics, or team sports (Raiola et al., 2015; Scamardella et al., 2025). When it comes to bocce, existing research is mostly centered on technical or historical aspects, while biomechanical, physiological, and, especially, anthropometric investigations are still lacking. Nonetheless, some preliminary studies conducted in recent years, particularly in the broader context of bocce sports (including Volo and Petanque), have shown that certain physical characteristics can significantly influence the effectiveness of the technical gesture, postural stability, precision, and neuromuscular endurance. Moreover, international studies on sports that share similarities with Raffa, such as archery, curling, or bowling, emphasize the importance of a balance between strength, fine motor control, and bodily symmetry (Cataldi et al., 2019). In these contexts, parameters such as the length of the dominant arm, symmetry between limbs, BMI, and lean mass distribution have shown correlations with performance quality (Balan et al., 2020). Therefore, the absence of a solid body of specific data for Raffa, and especially for the Juniores category, represents a significant gap that this study aims to begin addressing, by providing an original and focused contribution toward building a reference model for the physical and morphological evaluation of young bocce athletes (Firdaus, & Irfan, 2023).

This study was thus conceived to fill a gap in the current scientific landscape by proposing a detailed analysis of the anthropometric characteristics of young bocce players in the Raffa discipline. Through the collection and analysis of morphological data from a representative sample of Juniores-level athletes, the aim is to outline an ideal physical profile for the discipline, identifying any potential correlations between these characteristics and performance

levels. The methodological framework of the study is based on several key research questions, which represent the core of the scientific inquiry: What is the ideal height for a Juniores-level Raffa player? What is the ideal weight for such a player? Moreover, can we approximate the average body composition of such athletes with reasonable accuracy? And finally, is it possible to establish an anthropometric prototype of the national-level Juniores Raffa player?

In summary, the present article aims to provide a comprehensive and detailed overview of the anthropometric characteristics of young Raffa players, with the goal of identifying the ideal morphological parameters for high-level performance in this discipline. The research questions outlined above will guide the entire investigation, whose ultimate purpose is to enhance our understanding of the factors influencing performance in Juniores-level Raffa, while also offering concrete, operational insights for the sports world.

Materials and Methods

Study Design

The study was conducted according to a quasi-experimental comparative and transversal design, aimed at analyzing the anthropometric characteristics of young athletes practicing the Raffa specialty in the discipline of Bocce, in order to outline a possible ideal morphological profile for the Juniores category. A comparative study design was therefore adopted between two distinct groups of athletes: a research group composed of competitive subjects of national interest and a control group formed by non-competitive practitioners.

The adoption of a transversal design allows a precise photograph of the body characteristics of the subjects at a precise moment in their sporting career, providing useful data for the definition of youth performance standards.

The quasi-experimental design was chosen as it is particularly suitable for the sports field, where the randomization of subjects is not always possible for ethical, organizational or selection reasons. In this context, the division into natural groups still allows us to explore the correlations between specific physical characteristics and the level of sports performance, in a realistic perspective that can be applied to practice.

Within the design, the independent variable is represented by the level of sports practice (competitive vs non-competitive), while the dependent variables include the main anthropometric parameters measured: height, body weight, Body Mass Index (BMI).

In compliance with international ethical principles, the study was conducted in accordance with the dictates of the World Medical Association's Declaration of Helsinki, which regulates research with human subjects. All participants and their parents or legal guardians have received appropriate information on the purpose and modalities of the study and have provided written informed consent to participate. The measurements were carried out in full respect of the dignity, confidentiality and physical integrity of the subjects involved. The entire procedure was supervised by trained operators, able to guarantee the accuracy of the measurements and the safety of the athletes.

In conclusion, the design adopted, while presenting the typical limitations of quasi-experimental (absence of randomization, non-probability sample, observational nature), offers a solid framework to systematically explore the relevant anthropometric characteristics in Raffa at the competitive youth level, constituting a first step towards the construction of a reference performance model in the discipline.

Participants

The sample under study consists of twenty male athletes, aged between fourteen and eighteen, all belonging to the Juniores category, selected from among practitioners of the Raffa specialty. The participants were divided into two homogeneous groups of ten units each: the research group, made up of athletes of national importance (including winners of the absolute Italian title and medalists both individually and in teams at national level), and the control group, composed of practitioners of the Raffa discipline not included in federal competitive circuits. The selection of the athletes of the experimental group took place in collaboration with the federal technicians and the regional committees of the Italian Bocce Federation, in order to ensure the representativeness of the competitive level required. All participants and, when necessary, their parents or legal guardians, have provided informed consent to participate in the study.

Procedure

The data collection activities took place in the context of regional collegiate events, organized by the Italian Bocce Federation at the Campania Bocce Committee, in preparation for national competitions. The surveys were carried out during two technical internships, carried out in March and April 2025. Each athlete was subjected to two basic measurements: height, measured by means of a stadiometer in an orthostatic position, and body weight, measured through a digital scale calibrated and validated for sports medical use. The Body Mass Index (BMI) was calculated for each athlete using the standard formula (weight in kg divided by the square of the height in meters); however, since these subjects are adolescents (14–18 years), its interpretation has been made with reference to age- and sex-specific percentile values, as recommended by the main international scientific bodies, in order to take into account the natural variations related to pubertal growth and body development (Centers for Disease Control and Prevention, 2000; WHO, 2007). The data obtained were subsequently processed using descriptive statistical indices (mean, standard deviation, range) and compared between the two groups (research and control) to identify any significant differences and assess consistency with the research hypotheses formulated. The entire survey process was conducted by expert personnel in compliance with standardized anthropometric measurement protocols, in order to ensure the reliability and validity of the data collected.

Statistical Analysis

For the analysis of the collected data, several statistical tests were used in order to compare the anthropometric

characteristics between the research group (competitive athletes) and the control group (non-competitive athletes). The main variables analyzed were height, body weight, and body mass index (BMI).

First, a normality test was performed on the data to see if it followed a normal distribution. Because the study sample size was relatively small ($n=10$ for each group), the Shapiro-Wilk test, a specific test for small sample sizes, was used. This step was critical in determining which statistical test to use next. If the data were normally distributed, the t-test for independent samples would be applied to compare the means between the two groups. In the event that the data were not normally distributed, nonparametric tests, such as the Mann-Whitney U test, would have been used.

Next, descriptive parameters were calculated for each variable (height, weight, and BMI) within each group, including mean, median, standard deviation, and value ranges. These values provided an overview of the distribution and variability of the participants' anthropometric characteristics.

To compare differences between groups with regard to height, body weight, and BMI, the t-test for independent samples was used. This test made it possible to establish whether there were statistically significant differences between the two groups in relation to each of the variables measured. The null hypothesis (H_0) indicated that there were no differences between the groups, while the alternative hypothesis (H_1) stated that there were significant differences.

Once the BMI values for all participants had been calculated, the means of the two groups were compared using the t-test for independent samples. For each of the variables analyzed (height, weight and BMI), the results obtained were interpreted according to the significance value (p-value). A p-value of less than 0.05 was considered statistically significant, indicating that the observed differences between the groups were not due to chance. In addition, to have a measure of the magnitude of the differences, the effect size (Cohen's d) was calculated, which allows us to assess how significant the differences between the groups are, beyond statistical significance.

All data were analyzed using SPSS software (version 27.0, IBM Corp.), with the help of Excel 2021 for descriptive data management and charting.

Results

The analysis of the data collected concerned the main anthropometric variables of the subjects involved in the study: height, body weight and body mass index (BMI). The results were compared between the research group, made up of junior competitive athletes of national level, and the control group, made up of peers who are non-competitive practitioners of the Raffa specialty.

In terms of height (Fig.1, 2), subjects in the research group showed an average of 170.5 cm (range: 157–183 cm), while subjects in the control group had a slightly higher average of 173.5 cm (range: 162–184 cm). The t-test for independent samples found no statistically significant differences between the two groups ($t_{(18)} = 0.70$, $p = 0.492$), suggesting that height is not a relevant distinguishing factor between young competitive and non-competitive athletes in the discipline. The analysis of Cohen's d revealed a moderate

difference between the two groups with a value of -0.55, indicating that the control group is on average higher than the research group. Although the difference between the averages is visible, the effect is not particularly pronounced, suggesting that height is not a determining factor with a large incidence in performance between the two groups.

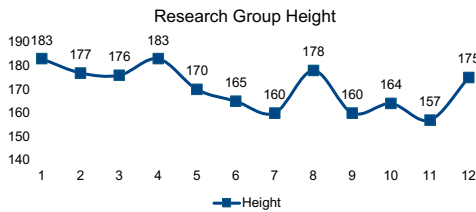


Fig. 1. Average height research group

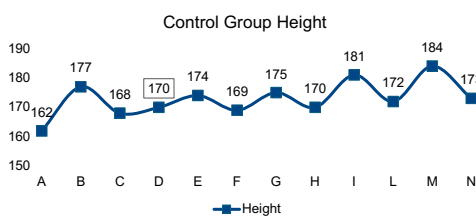


Fig. 2. Average height control group

More marked, however, are the differences that emerged in terms of body weight (Fig. 3, 4). The athletes in the research group showed an average weight of 65.8 kg (range: 42-87 kg), while the peers in the control group showed a significantly higher average value of 74.5 kg (range: 68-93 kg). Statistical comparison revealed a significant difference between the groups ($t_{(18)} = -2.78$, $p = 0.012$), indicating that agonist subjects tend to have a lower body weight than non-agonist peers. The Cohen's d value for weight is -1.09, indicating a significant and impressive difference between the two groups. The research group, therefore, has a lower body weight than the control group. This suggests that Raffa bowlers in the research group tend to be lighter than players in the control group.

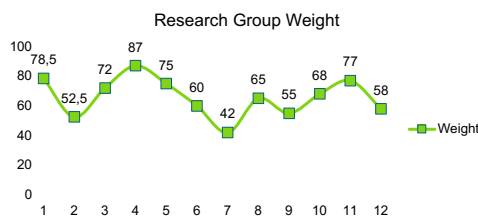


Fig. 3. Average weight of the research group

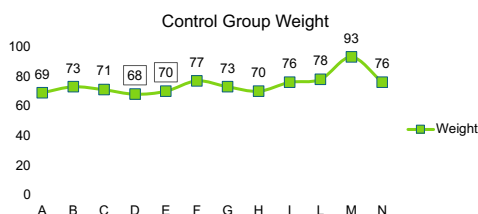


Fig. 4. Average weight control group

A similar picture was observed in the analysis of Body Mass Index (BMI) (Fig 5, 6). BMI was calculated for each subject using the weight (kg) / height (m)² formula, and was interpreted according to the criteria for adolescent subjects aged 14 to 18 years, referring to the percentile-specific tables for sex and age, as indicated by Cole et al. (2000). The results show that the research group is distributed as follows: 16.67 % of athletes fall into the underweight range, 50 % into the normal weight range, 25 % overweight, and 8.33 % into class I obesity. On the contrary, in the control group, 50 % of athletes are normal weight, while the remaining 50 % are overweight; no subject is underweight or obese. Again, the t-test showed a statistically significant difference between the two groups ($t_{(18)} = -2.80$, $p = 0.012$), confirming that the weight profile of competitive athletes tends to be more in line with optimal body composition conditions than non-competitive peers. Cohen's d value for BMI is -0.71, indicating a moderate difference between the two groups, with the research group having a lower average BMI than the control group. This suggests that bowlers in the research group tend to have a relatively lower weight than players in the control group, a factor that could be related to physical characteristics specific to the Raffa discipline.

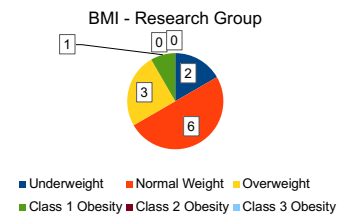


Fig. 5. BMI distribution research group

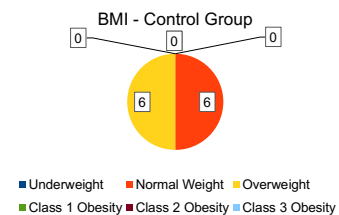


Fig. 6. Control Group BMI Distribution

These results, taken together, suggest that competitive junior athletes of the Raffa specialty exhibit anthropometric characteristics closer to an ideal reference model, particularly with regard to body weight and body mass index. Despite the absence of a significant difference in height, the overall profile appears consistent with a higher level of physical preparation and weight control.

Discussion

The aim of this study was to analyze the anthropometric characteristics of young athletes in the Raffa specialty, with particular attention to height, weight and BMI, in order to identify any correlations between these variables and sports performance. The authors also sought to compare

these data with those of a control group of non-competitive practitioners, to assess the physical differences between national-level junior athletes and their non-competitive peers.

The first result that emerged from the study concerns the average height of the young athletes of the Raffa, which turns out to be 170.5 cm. This figure is lower than the national average of young Italians, which is around 177 cm, but this difference could have interesting biomechanical implications. Athletes with a smaller stature could benefit from greater stability when throwing the apparatus, thanks to a lower center of gravity. This could positively affect the precision and control of the technical gesture, favoring greater postural stability during the throwing gesture (Badruzaman, 2021; Paciorek, 1992; Miao et al., 2017).

The average height of the research team may suggest a preference for athletes who do not excel in height, but who benefit from better body control and a more advantageous stable position. This feature could prove useful for the type of movement required in the Raffle, which involves postural stability and accuracy in throwing (Şimşek et al., 2024; Horowitz, 2009; Turkmen et al., 2013).

The results obtained are consistent with some evidence in the scientific literature. Although sports such as basketball require a tall stature, sports such as archery or curling, which require precision and stability, show a preference for athletes with an average or smaller stature. Eler (2018) noted that the average height of Raffa adult national athletes is around 177 cm, while the young athletes in our study are below this average, suggesting that Raffa's specialty does not favor very tall athletes (Helmi et al., 2024a).

The average weight of the athletes in the research group was 65.8 kg, with an average BMI of 22.63, which falls within the normal weight range, a sign of an adequate physical condition for a competitive athlete. This value is in line with the expectation of an athlete who practices the Raffa at a national level. However, the BMI figure shows that 33.3% of athletes are overweight or even class I obese, which could indicate a certain inattention to conditional physical training, and especially to physical culture in relation to the game of bowls. Although the research team has a normal BMI average, the presence of overweight athletes suggests that some young people may not be fully prepared physically (Helmi et al., 2021).

The weight and BMI data highlights a positive aspect, with most athletes in an appropriate physical condition for the competitive level, but also a certain criticality, with a significant percentage of athletes overweight or even obese. This may reflect a lack of attention to physical preparation, which is an important factor in maintaining a competitive level in a sport that, although technical, also requires endurance and agility (Helmi et al., 2024b).

The results of the research team are partly in line with the data of Eler et al. (2018), where the average BMI of senior athletes in the Raffa is around 22.94, very close to the figure of 22.63 observed in our sample. However, the presence of athletes with overweight or obesity is an issue that requires attention, as it has been found that the optimal physical condition in athletes of precision and coordination sports, such as Raffa, is that of a BMI in the normal weight range or slightly lower (Hafidz et al., 2024; Costa, 2021).

As for the control group, the average height was 173.5 cm, a higher value than the research group, but still close to the

national average of young Italians (Epicentro, 2025). The average weight, on the other hand, was 74.5 kg, with a higher average BMI than the research group, indicating that most athletes in the control group are in the overweight range, with a percentage of 50% in this condition. These findings may reflect a lack of focus on physical preparation for bowls, or a non-competitive approach to physical training, suggesting that many non-competitive practitioners do not have a specific conditional training regimen (Irawan et al., 2024; Kopp, 2022; Mardiah, 2022).

Data from the control group confirm that, without a structured training program and attention to physical preparation, practitioners tend to develop less than ideal physical conditions, with a significant percentage being overweight. This is a worrying aspect, which underlines the importance of promoting a sports culture even among non-competitive athletes, in order to ensure a balanced approach to sports practice.

The distribution of BMI in the control group aligns with data reported in previous studies examining the physical status of Italian adolescents (Maffei et al., 2023), where there is a worrying trend towards overweight and obesity among young people. The literature also supports the need for awareness-raising interventions to improve physical preparation, not only among competitive athletes, but also among non-competitive practitioners (Irawan, 2019; Nurhasan et al., 2024).

In general, the results obtained in the present study are in line with the initial research hypotheses, highlighting some common anthropometric characteristics among young Raffa athletes. Although physical preparation is adequate in many cases, the presence of overweight or obese athletes in both the research group and the control group underlines the importance of a conditional training program that accompanies sports technique. It is hoped that future research will explore the somatotype of junior athletes, using methods such as those of Heath & Carter (1967), to gain an even deeper understanding of the ideal physical characteristics for Raffa's specialty.

The study in question therefore aimed to explore the anthropometric characteristics of junior athletes in the Raffa specialty, an aspect still little explored in the scientific literature. The results obtained provide interesting and useful data to improve the physical preparation of young athletes and help to fill a gap in the sports research landscape.

However, the study has some limitations that must be considered. First, the sample size is relatively small, with only 20 athletes involved, divided into two groups of 10 participants each. This limited number of subjects may not fully represent the total population of junior athletes in the Raffa, reducing the ability to generalize results. A larger sample would allow us to have a more accurate and representative view of the physical characteristics of Bocce athletes. In addition, the study focused mainly on three variables: height, weight and BMI, without including other relevant parameters such as somatotype or body composition, which could provide additional information on the physical condition of the athletes. The effect of other factors, such as diet or lifestyle, that could affect athletes' body weight and physical health was also not considered. In addition, the sample was not randomly selected, and this could introduce biases, particularly regarding the difference between the

research group (competitive athletes) and the control group (non-competitive athletes). Finally, the fact that the study is cross-sectional represents another limitation, since changes over time in the physical characteristics of athletes have not been observed, which could evolve with age and with the improvement of technical and physical skills.

Despite these limitations, the study has numerous strengths. First of all, the contribution to the scientific literature is significant, as it offers food for thought on an area that has not been much explored: the physical characteristics of junior athletes in the Raffa. Objective data, such as height, weight and BMI, represent parameters that are easily repeatable and can be used by coaches and sports professionals to monitor the health and physical condition of athletes. In addition, the comparison between competitive and non-competitive athletes allows us to highlight significant differences in the level of physical preparation, helping to better understand the importance of training for the Raffa specialty. The results obtained are also useful for designing targeted training programs that can improve the physical condition of young practitioners. Finally, the results of this study are consistent with other previous research, confirming the robustness and reliability of the data.

Therefore, although the study has some limitations related to the sample size and the lack of additional variables, it still offers a significant contribution to the understanding of the physical characteristics of junior athletes in the Raffa. The information collected can be used as a basis for further research and for the improvement of training practices for young Bocce athletes. Future studies could explore these issues by including a larger sample, additional variables, and a longitudinal design to observe the evolution of physical characteristics over time.

Conclusions

The sport of bocce, in particular in the specialty of the Raffa, has seen a growing development at a competitive level in recent decades, with an increasing attention to physical preparation and the selection of young talents. Although the scientific literature regarding the anthropometric characteristics of bocce athletes, and in particular of young Raffa players, is still limited, this study sought to fill part of this gap, exploring the physical characteristics of national-level junior players. The analysis of variables related to height, weight and BMI has provided interesting insights to understand the physical peculiarities of this category of athletes and to develop future specific preparation models for the discipline.

The results obtained revealed that the average height of Raffa's junior athletes is 170.5 cm, a figure that may appear lower than the average height of Italian adolescents, but which may confer biomechanical advantages related to greater stability and a lower center of gravity during the technical gesture of the throw. The average weight of 65.8 kg is in a normal weight range, with a BMI of 22.63, consistent with the physical characteristics of a national-level competitive athlete. However, the data also show that a significant proportion of athletes are overweight or even class I obese, an aspect that underlines the importance of adequate physical preparation and athletic conditioning, which is often neglected in this sport. In addition, the

comparison with the control group, made up of non-competitive practitioners, highlighted evident differences in physical composition, in line with the initial hypotheses.

The practical implications of the study manifest themselves on several levels. Firstly, from a scientific point of view, the work contributes to filling a gap in the Italian and international sports literature, providing useful data to the academic and sports community. Secondly, on a practical level, the results can be used by sports federations (such as the Italian Bocce Federation) to improve youth selection processes, to design personalized training paths and to optimize talent development strategies. In addition, sports training schools, functional assessment centers and coaches themselves will be able to have more objective tools to assess the suitability of athletes during the recruitment phase, but also to monitor progress over time and intervene in a targeted way on physical preparation. Finally, the work aims to contribute to a greater professionalization of the sport of bocce, bringing it closer and closer to consolidated disciplines in terms of scientific analysis of the athletic gesture and physical preparation. A distinctive aspect of this study lies in the integrated and multidimensional approach to anthropometric evaluation. In this way, the aim is to build an in-depth descriptive model, which can serve as a reference for future comparative studies, also in other bowling specialties or in sports similar to technical requirements.

Looking ahead, future research developments could include the integration of more detailed measurements of body composition (particularly the percentage of lean and fat mass) and somatotype, using validated protocols such as that of Heath & Carter. The introduction of a larger and more diverse sample, including athletes of different age groups and from different backgrounds, could allow for more general results that are applicable at national and international level. A longitudinal design, which allows athletes' physical changes to be monitored over time, would be particularly useful for understanding how physical characteristics evolve with age and competitive experience, as well as for identifying the best training strategies during various stages of development.

In conclusion, this study represents a significant first step in understanding the anthropometric characteristics of the young bowler in the Raffa, with implications for the training, selection and development of talent in this sport. While there are still many areas to explore, the information gained is a valuable starting point for improving athletes' physical fitness and contributing to their success in competitive competition.

Conflict of Interest

The authors declare that there is no conflict of interest.

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Антропометричні характеристики юних спортсменів з бочче за спеціалізацією «Раффа»: Аналіз фізичних параметрів юних гравців національного рівня

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 8 с., 6 рис., 33 джерела.

Історія питання. За останні десятиліття бочче як різновид спорту і, зокрема, спеціалізація «Раффа», зазнали значного конкурентноспроможного розвитку, проте наукова література щодо антропометричних характеристик спортсменів, особливо серед молоді, представлена досі обмежено.

Мета дослідження. Метою цього дослідження було проаналізувати фізичні характеристики юних раффа-гравців на національному рівні, зосередивши увагу на антропометричних показниках, як-от зріст, вага та індекс маси тіла (ІМТ).

Матеріали та методи. Задля проведення базових вимірювань під час регіональних змагань, вибірку із двадцяти спортсменів розподілено на дослідницьку групу, що складалася з десяти спортсменів національного рівня, і контрольну групу з десяти практикуючих осіб, які не брали участі у змаганнях.

Результати. За результатами дослідження середній зріст досліджуваної групи становив 170,5 см, середня вага — 65,8 кг, середній ІМТ — 22,63, що вказує на стан нормальної ваги. Однак 33,3 % спортсменів у досліджуваній групі мали надмірну вагу або ожиріння І ступеня, що свідчить про необхідність приділяти більшу увагу фізичній підготовці. Отримані дані було порівняно із показниками контрольної групи, яка мала середній зріст 173,5 см, середню вагу 74,5 кг та розподіл ІМТ, за яким 50 % спортсменів класифіковано як особи з надмірною вагою. Результати обговорено відповідно до вихідних гіпотез та наявних літературних даних.

Висновки. У цьому дослідженні представлено важливу інформацію для розробки персоналізованих тренувальних програм та відбору молодих талантів, що підкреслює важливість належної фізичної підготовки. Подальші перспективи включають поглиблення аналізу соматотипу та використання більших та різноманітніших вибірок.

Ключові слова: антропометрія, спорт, тренування, спортсмени, фізична результативність.

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Clarifying the Impact of Small-Sided Games and HIIT on Anaerobic Endurance in Adolescent Hockey Players

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Abstract

Background. Given the sport's complex aerobic-anaerobic demands, optimizing training methodologies is crucial for improving players' repeated sprint ability, sustaining effort throughout matches, and enhancing overall performance. While hockey requires significant anaerobic power for explosive movements and sprints, the intermittent nature of the game also places considerable demands on aerobic systems for recovery between high-intensity efforts.

Objectives. This study aimed to evaluate and compare the effectiveness of Small-Sided Games (SSG) and High-Intensity Interval Training (HIIT) in enhancing anaerobic endurance among adolescent field hockey players.

Materials and methods. A total of 36 adolescent male hockey players (aged 15-17 years) participated in this study and were randomly assigned to three groups: SSG (n = 12), HIIT (n = 12), and an Active Control Group (ACG) (n = 12). The intervention lasted for six weeks, with each training group engaging in their respective training modalities three times per week. Anaerobic endurance was evaluated through the Running-Based Anaerobic Sprint Test (RAST) both prior to and following the intervention. A Two-Way Mixed ANOVA was conducted to analyze the interaction between time (pre-test vs. post-test) and group assignment.

Results. Both the SSG and HIIT groups demonstrated significant improvements in anaerobic endurance compared to the ACG. The SSG group exhibited a greater reduction in RAST values (5.03 %) than the HIIT group (3.71 %). Statistical analysis revealed a significant main effect of time and group ($F = 14.80$, $p < 0.001$, $\eta^2_p = 0.47$), indicating a meaningful impact of both interventions. Post hoc comparisons showed that the SSG group outperformed the HIIT group, though both significantly improved anaerobic endurance compared to the control.

Conclusions. This study confirms the efficacy of both SSG and HIIT in enhancing anaerobic endurance in adolescent hockey players, with SSG demonstrating slightly superior benefits. The findings suggest that integrating sport-specific drills, as seen in SSG, may yield greater physiological and tactical improvements than traditional HIIT protocols. Further research is needed to explore long-term adaptations, injury risk, and the potential benefits of combining both training methods for optimal performance enhancement.

Keywords: anaerobic endurance, adolescent athletes, field hockey, repeated sprint ability.

Introduction

Field hockey is an extremely demanding sport physically as it requires a mix of anaerobic endurance, technical skill, and tactical awareness. Players have to repeatedly perform high-intensity sprints, rapid changes of direction, and precise

decision-making under fatigue, making anaerobic endurance a critical component of performance (Ihsan et al., 2017). The physiological demands of hockey are well-documented, with contemporary studies showing that players cover approximately 5-8 km during a match, of which 1.5-2.5 km are high-intensity efforts, including sprints and accelerations (McGuinness et al., 2019; Noblett et al., 2023). These efforts are interspersed with brief recovery periods, highlighting the importance of repeated sprint ability (RSA) and the capacity to recover quickly between bouts of intense activity (Taylor & Jakeman, 2022). Additionally, the tactical demands of

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hockey, such as maintaining positional awareness, executing quick passes, and making split-second decisions, further compound the physical challenges (Weigel et al., 2015). In order to meet these demands, training programs have to be designed in a way that address both the physiological and tactical aspects of the game. However, many traditional training approaches fail to provide the intensity and specificity required to adequately improve both aerobic and anaerobic performance, particularly in adolescent athletes who are still developing physically and technically (Sulyma et al., 2017). This gap in training effectiveness underscores the need for well-designed, sport-specific programs that cater to the unique needs of young hockey players.

In recent years, two training modalities have emerged as promising tools for enhancing hockey performance: Small-Sided Games (SSGs) and High-Intensity Interval Training (HIIT). SSGs are modified versions of the game, typically involving fewer players, smaller playing areas, and adapted rules. These games are designed to replicate the intensity and tactical demands of match play while simultaneously developing technical skills and physical fitness (Arslan et al., 2020; Clemente et al., 2021). Recent studies have shown that SSGs can elicit heart rate responses between 88-96% of maximum heart rate, which aligns with the physiological demands observed during competitive matches (Noblett et al., 2023). This makes SSGs an effective tool for improving both physiological capabilities and sport-specific skills, such as agility and decision-making, which are crucial for hockey performance (Arslan et al., 2020; Clemente et al., 2022). On the other hand, HIIT involves short bursts of intense exercise followed by periods of rest or low-intensity activity. This training method has been widely recognized for its ability to improve both aerobic and anaerobic performance markers, such as maximal oxygen uptake (VO_{2max}), anaerobic threshold, and repeated sprint ability (Kunz et al., 2019; Ouertatani et al., 2022). For instance, Paul et al. (2016) found that HIIT protocols consistently produced superior improvements in VO_{2max} compared to traditional training methods in team sport athletes (Paul et al., 2016). In the context of hockey, structured HIIT programs have been shown to enhance players' ability to maintain high-intensity efforts during matches (Quezada et al., 2021). Despite the proven efficacy of both SSGs and HIIT, there is limited research directly comparing their effectiveness in developing anaerobic endurance, particularly among adolescent hockey players. While SSGs offer the advantage of integrating technical, tactical, and physiological demands, HIIT provides a more controlled environment for targeting specific physiological adaptations. This raises important questions about which training modality is more effective for improving anaerobic endurance in young athletes. Additionally, the influence of training modality on sport-specific performance measures, such as agility and decision-making, remains inadequately explored (Narayanan et al., 2025). Furthermore, optimal programming parameters for both SSGs and HIIT, including work-to-rest ratios and progression models, have yet to be empirically validated for adolescent athletes (Narayanan et al., 2025). Another critical consideration is the interaction between training modality and biological maturation status. Adolescence is a period of rapid physiological development, and the rate at which young athletes mature can significantly impact their

response to training (Lloyd et al., 2016). For example, early-maturing athletes may experience greater improvements in strength and power, while late-maturing athletes may benefit more from training that emphasizes technical and tactical development. Despite the importance of this factor, few studies have considered the developmental stage of adolescent athletes in their experimental design, leaving a gap in our understanding of how to optimize training for this population (Lloyd et al., 2016). This study aims to address these limitations by systematically comparing the effects of SSGs and HIIT on anaerobic endurance in adolescent hockey players. To evaluate anaerobic endurance, players were tested using the Running-Based Anaerobic Sprint Test (RAST) before and after a 6-week intervention program. Research validates the RAST as a reliable measure of anaerobic power and capacity, making it an effective tool for assessing the impact of training on repeated sprint ability, which time-motion analyses have established as a critical component of hockey performance (Zagatto et al., 2009). By focusing on this specific metric, the study provides a clear and objective comparison of how SSGs and HIIT influence anaerobic endurance in young athletes.

It is hypothesized that both SSGs and HIIT will significantly improve anaerobic endurance, as measured by the RAST, in adolescent hockey players. However, due to the sport-specific nature of SSGs, which integrate technical, tactical, and physiological demands, it is hypothesized that SSGs may lead to slightly greater improvements in anaerobic endurance compared to HIIT. As youth hockey continues to evolve with increasing physical and tactical demands, evidence-based training methods become crucial for optimal athlete development. This study aims to provide practitioners with validated guidelines for implementing training methods that effectively develop anaerobic endurance while considering the unique characteristics of adolescent athletes. Furthermore, the findings will contribute to the broader understanding of training specificity and transfer in youth team sports, potentially influencing future approaches to long-term athlete development.

Materials and methods

Participants

This study involved 36 adolescent hockey players aged 15-17 years, active members of a regional hockey training academy in Gwalior, Madhya Pradesh, India. The participants were divided into three groups: Small-Sided Games (SSG) ($n = 12$), High-Intensity Interval Training (HIIT) ($n = 12$), and an Active Control Group (ACG) ($n = 12$). The average age of the participants was 16.38 ± 0.76 years in the SSG group, 16.15 ± 0.89 years in the HIIT group, and 16.23 ± 0.83 years in the ACG group. The average weight of the participants was 53.53 ± 2.69 kg in the SSG group, 54.07 ± 2.84 kg in the HIIT group, and 53.07 ± 2.62 kg in the ACG group. The participants' average height was 159.92 ± 2.25 cm in the SSG group, 159.69 ± 2.28 cm in the HIIT group, and 159.46 ± 2.18 cm in the ACG group. All players had a minimum of three years of competitive experience. Prior to the commencement of the study, both adolescent athletes and their guardians were thoroughly informed about the study's objectives, procedures, potential risks, and

benefits. A comprehensive information sheet detailing the nature of the interventions and assessments was provided to ensure transparency. To secure informed consent, athletes and their guardians were encouraged to ask questions and seek clarification from the research team. Written informed consent was obtained from both the athletes and their legal guardians, who voluntarily signed consent forms after being assured of their right to withdraw from the study at any time without any impact on their training programs or athletic development. All personal data and performance outcomes were kept strictly confidential, with participants identified through unique codes for data collection and analysis. It adheres to the ethical guidelines specified in the Declaration of Helsinki, emphasizing respect for human participants, confidentiality, voluntary involvement, and the right to withdraw at any point without repercussion (World Medical Association, 2013).

Procedure

A pre-experimental design with two groups and a pre-test-posttest structure was utilized. Anaerobic endurance was measured using the Running-Based Anaerobic Sprint Test (RAST) both before and after a six-week intervention program. Data collection was conducted using precise and validated instruments. The RAST, with a validity coefficient of 0.897 and a reliability score of 0.919, was employed to assess anaerobic endurance performance (Bongers et al., 2015; Wibisana, 2020). The SSG group followed a structured small-sided games program, the HIIT group underwent a high-intensity interval training protocol, and the ACG continued with their regular activities without any specific training program. Post-intervention, the data were analyzed to compare the effectiveness of the two methods. Each group participated in the training program three times per week (Tuesday,

Thursday, and Saturday) for a duration of six weeks. Every session commenced with a warm-up, proceeded with the implementation of the program or game, incorporated a tactical phase, and concluded with a cool-down. The program was systematically followed throughout the study period. Table 1 outlines the SSG phase, and Table 2 details the HIIT phase. For the SSG group, the intensity, repetitions, distance, and rest time were adjusted weekly to reflect the progression of the program. Similarly, for the HIIT group, the intensity, repetitions, and rest periods were modified each week to align with the changing demands of competition. Intensity was carefully monitored using structured training protocols based on predetermined work-to-rest ratios, exercise duration, and intensity levels. However, real-time heart rate monitoring was not used during the sessions.

The athletes were not explicitly matched for fitness levels before the intervention. Instead, they were assigned to the three groups using stratified random sampling to ensure a balanced distribution of participants across the SSG, HIIT, and ACG groups. This approach helped minimize bias and ensured that each group had a similar mix of players in terms of age, experience, and baseline performance. By using this method, the study aimed to create comparable groups while maintaining the practicality of implementing the training programs in a real-world setting. This design allowed for a clear comparison of the effects of SSG and HIIT on anaerobic endurance, while the ACG served as a baseline to account for any external factors that might influence the results.

Each group trained three times per week for 45 minutes under controlled supervision. All sessions included a standardized warm-up and cool down phase. Players underwent the RAST again to evaluate changes in anaerobic endurance, comparing pre and post test scores.

Statistical Analysis. Statistical analyses were performed using SPSS version 26, with a significance threshold of p

Table 1. Small-Sided Games (SSG) Program

Week	Meeting	Type of SSG Activity	Training Description
1	1-3	5v5	5 repetitions, with each repetition lasting 2 minutes, followed by a 2-minute rest period (1:1 work-to-rest ratio). The training was structured into 3 sets, with a 4-minute rest interval between sets (1:2 ratio). The activity took place within a 25×20m area, performed at an intensity of 75%.
2	4-6	4v4	5 repetitions, each lasting 2 minutes, with a 2-minute rest period between repetitions, maintaining a 1:1 work-to-rest ratio. The program comprised 3 sets, with a 4-minute rest interval between sets, following a 1:2 ratio. The exercises were performed within a 20×15-meter area at an intensity of 80%.
3	7-10	3v3	5 repetitions, each lasting 2 minutes, with a 2-minute rest period between repetitions, maintaining a 1:1 work-to-rest ratio. A total of 4 sets were performed, with a 4-minute recovery time between sets, following a 1:2 ratio. The exercises were conducted within a 15×12-meter area at an intensity level of 80%.
4	11-13	2v2	5 repetitions, each lasting 1 minute, followed by a 1-minute rest period, maintaining a 1:1 work-to-rest ratio. A total of 3 sets were performed, with a 3-minute rest interval between sets, following a 1:3 ratio. The exercises were conducted within a 12×10-meter area at an intensity of 90%.
5	14-16	1v1	5 repetitions, each lasting 1 minute, with a 1-minute rest period between repetitions, maintaining a 1:1 work-to-rest ratio. The program comprised 3 sets, with a 3-minute rest interval between sets, following a 1:3 ratio. The exercises were conducted within an 8×6-meter area at an intensity of 95%.
6	17-20	3v3	5 repetitions, each lasting 2 minutes, with a 2-minute rest period between repetitions, maintaining a 1:1 work-to-rest ratio. A total of 3 sets were performed, with a 4-minute recovery time between sets, following a 1:2 ratio. The exercises were conducted within a 15×12-meter area at an intensity of 80%.

Table 2.High-Intensity Interval Training Program

Week	Meeting	Reps	Training Description
1	1-3	6	23m line sprints; Rest between reps: 1:2; Area: Between 23m lines; Intensity: 75 %
2	4-6	6	Baseline to halfway line; Rest between reps: 1:2; Area: Half field length; Intensity: 80 %
3	7-10	6	Diamond running pattern (cons); Rest between reps: 1:2; Area: 25×25m square; Intensity: 80 %
4	11-13	5	Full field shuttles; Rest between reps: 1:3; Area: Full field length; Intensity: 90 %
5	14-16	5	Circle-to-circle sprints; Rest between reps: 1:3; Area: Between Shooting circles; Intensity: 95 %
6	17-20	6	Zigzag sprints with ball; Rest between reps: 1:2; Area: 30×20m; intensity: 80 %

< 0.05. Descriptive statistics, including mean and standard deviation, were calculated for all measured variables. Before conducting inferential analysis, data normality was evaluated using the Shapiro-Wilk test. To examine the differential effects of training interventions, a Two-Way Mixed ANOVA was performed with time (pre-test vs. post-test) as a within-subject factor and group (SSG, HIIT, Control) as a between-subject factor. This approach enabled the assessment of (1) the main effect of time, indicating whether anaerobic endurance improved across all groups; (2) the main effect of group, determining whether training interventions differed in effectiveness; and (3) the interaction effect (time*group), evaluating whether training-induced adaptations varied across groups. Paired t-tests were applied within each group to assess intra-group changes from pre- to post-intervention. Effect sizes, represented by partial eta squared (η^2_p), were calculated to quantify the magnitude of observed differences (Cohen, 1988). For all statistical tests, results were interpreted in accordance with best practices for sports science research, ensuring methodological rigor and reproducibility.

Results

The findings of the study, as illustrated in Table 3, illustrate the impact of SSG and HIIT on anaerobic endurance, measured using the RAST in adolescent hockey athletes. The pre and post intervention data indicate that both experimental groups SSG and HIIT demonstrated improvements in anaerobic endurance, while the ACG showed negligible change.

Table 3 the SSG group exhibited a significant reduction in RAST values from 37.33 ± 0.89 to 35.45 ± 0.90 , reflecting a 5.03 % improvement. Similarly, the HIIT group showed a decrease from 36.62 ± 1.22 to 35.26 ± 1.09 , corresponding to a 3.71 % enhancement. In contrast, the ACG group maintained relatively stable values (36.35 ± 0.80 to 36.34 ± 0.82), with a negligible change of -0.02 %. Statistical analysis using Two-Way Mixed ANOVA revealed a significant main effect of training interventions on anaerobic endurance, with an F-value of 14.80 ($p < 0.001$), indicating a substantial difference between groups. The partial eta squared ($\eta^2_p = 0.47$) suggests a large effect size, confirming the meaningful impact of the

interventions. These findings support the efficacy of both SSG and HIIT in enhancing anaerobic endurance, with SSG demonstrating a slightly greater improvement.

The paired t-test analysis, as presented in Table 4, evaluates the within-group differences in anaerobic endurance (RAST) following the intervention period for each training group. The results indicate a significant improvement in anaerobic endurance in both the SSG and HIIT groups, while no meaningful change was observed in the ACG.

Table 4. Paired t-test Analysis of Small-Sided Games and High-Intensity Interval Training on Anaerobic Endurance (RAST) in Adolescent Hockey Athletes

Variable	Group	SE	t	p
RAST	SSG	.32	5.84	<0.001
	HIIT	.29	4.68	<0.001
	ACG	.02	.50	0.623

Table 4 for the SSG group, the paired t-test revealed a statistically significant reduction in RAST values ($t = 5.84$, $p < 0.001$), with a standard error (SE) of 0.32, confirming a substantial improvement in anaerobic endurance following the intervention. Similarly, the HIIT group exhibited a significant enhancement in anaerobic endurance, as evidenced by a t-value of 4.68 ($p = <0.001$) and an SE of 0.29. These findings suggest that both training modalities effectively enhanced anaerobic performance. In contrast, the ACG group did not demonstrate a statistically significant change in RAST values ($t = 0.50$, $p = 0.623$), with a minimal standard error of 0.02. This result indicates that participants in the active control group maintained their baseline anaerobic endurance levels without significant improvement.

Discussion

This study compared the effectiveness of SSG and HIIT in improving anaerobic endurance among youth hockey players. As hypothesized, the results showed that both training methods significantly boosted anaerobic performance, as measured by the RAST. These findings are consistent with

Table 3. Analysis of Small-Sided Games and High-Intensity Interval Training on Anaerobic Endurance (RAST) in Adolescent Hockey Athletes

Variable	Groups	Pre data M $\pm$ SD	Post data M $\pm$ SD	Δ (%)	SS	F	p	η^2_p
RAST	SSG	37.33 $\pm$.89	35.45 $\pm$.90	-5.03	11.17	14.80	<0.001	.47
	HIIT	36.62 $\pm$ 1.22	35.26 $\pm$ 1.09	-3.71				
	ACG	36.35 $\pm$.80	36.34 $\pm$.82	-0.02				

previous research on SSG and HIIT in team sports (Kunz et al., 2019) and support their use in structured hockey training programs. The improvements in anaerobic endurance can be linked to the physiological adaptations triggered by both SSG and HIIT (Iacono et al., 2015). Specifically, the SSG group saw a 5.03% reduction in RAST values, while the HIIT group showed a 3.71% reduction. This highlights the effectiveness of both approaches in enhancing short-duration, high-intensity performance, which is crucial for hockey, where repeated bursts of speed and power are essential. The novel contribution of this research lies in being the first to directly compare these training modalities in field hockey, particularly within the adolescent population. While studies have examined SSG and HIIT separately in various sports, our findings uniquely demonstrate their comparative efficacy for field hockey-specific anaerobic adaptations. Furthermore, this study advances the existing literature by identifying the parameters of SSG that yield optimal training stimuli for hockey, specifically the progression from 5v5 to 1v1 formats and their subsequent physiological impact. The established work-to-rest ratios (1:1 to 1:3) and spatial constraints (25×20m to 8×6m) documented here represent novel, evidence-based guidelines for field hockey coaches working with adolescent athletes. These results are consistent with trends reported by Ansori et al. (2024), who observed improvements in anaerobic endurance following both SSG and HIIT in young football players, with SSG showing a slightly stronger effect (Ansori et al., 2024). While football and field hockey differ in match structure and field size, the comparison provides a useful perspective on the potential effectiveness of SSG-based training.

One possible reason SSG led to slightly greater improvements could be the integration of neuromuscular adaptations, such as agility and coordination, alongside physiological conditioning (Clemente et al., 2021). Unlike HIIT, which primarily focuses on metabolic adaptations, SSG requires players to perform sport-specific movements, rapid changes of direction, and quick decision-making under fatigue. These demands likely stimulate neuromuscular pathways, enhancing motor skills and coordination, which are critical for hockey performance (Clemente et al., 2022). For example, the constant stop-and-go nature of SSG mimics the dynamic movements required during a game, potentially leading to better agility and faster reaction times (Arslan et al., 2020). This could explain why SSG had a slight edge over HIIT in improving anaerobic endurance, as it combines physical and tactical elements in a way that HIIT does not. A particularly innovative finding from our study is the identification of a potential "transfer advantage" in SSG training, where physiological adaptations appear to be more effectively translated into sport-specific performance gains. This suggests a new framework for understanding training specificity in field hockey, where the contextual similarity between training stimulus and competitive demands may amplify adaptation responses beyond what physiological markers alone would predict. The superior improvement in RAST performance following SSG training (5.03% vs. 3.71% in HIIT) presents new evidence that the neural and tactical learning occurring simultaneously with physiological conditioning may create a synergistic effect not previously quantified in hockey training literature.

From a physiological perspective, HIIT is known to heavily recruit fast-twitch muscle fibres, which are essential for explosive movements like sprinting, rapid accelerations,

and intense braking (MacInnis & Gibala, 2017). This type of training improves the efficiency of anaerobic glycolysis and enables muscles to resynthesise phosphocreatine, allowing players to sustain high-intensity efforts for longer periods (Ouertatani et al., 2022). However, while HIIT excels in building metabolic capacity, it doesn't fully replicate the tactical and decision-making demands of hockey. On the other hand, SSG not only triggers similar physiological responses but also enhances tactical awareness and decision-making. For instance, Arslan et al. (2020) found that SSG improves players' ability to read the game, anticipate opponents' moves, and execute skills under pressure (Arslan et al., 2020). These cognitive and tactical benefits may give SSG an edge when it comes to transferring improvements to actual game performance (Clemente et al., 2021). Our research makes a significant contribution to field hockey training periodization models by demonstrating that the established principles of progressive overload must incorporate not only physiological but also neurocognitive and sport-specific technical parameters. The findings suggest that training prescription in hockey should evolve beyond traditional models focused primarily on cardiovascular and metabolic adaptations to include considerations of tactical learning integration. This represents a paradigm shift in how training adaptations are conceptualized in intermittent team sports like field hockey, distinguishing our work from studies in continuous endurance sports or strength-power athletic domains.

The improvements seen in both SSG and HIIT can directly translate to better on-ground performance. For example, enhanced anaerobic endurance means players can recover faster between shifts, allowing them to maintain high-intensity efforts throughout the game. This is particularly important in hockey, where quick transitions and counterattacks are key to gaining an advantage. Faster recovery also means players can sustain their speed and power during critical moments, such as breakaways or defensive plays. Additionally, the agility and coordination developed through SSG can improve a player's ability to navigate tight spaces, evade opponents, and execute precise movements, all of which are essential for success in hockey (Budiman, 2022). While the findings of this study are promising, there are several limitations that need to be addressed. First, the study only included male participants, which limits its applicability to female athletes. Future research should explore whether similar results are observed in female hockey players, as physiological and tactical responses to training can vary between genders. Second, the six-week intervention period may not be sufficient to assess long-term adaptations. Longer studies are needed to determine whether the improvements in anaerobic endurance are sustained over time and how they impact overall performance in competitive settings. Another limitation is the reliance on RAST as the sole measure of anaerobic endurance. While RAST is a valid and reliable test, it doesn't capture other important aspects of performance, such as agility, reaction time, or technical skills. Incorporating additional measures, like time-motion analysis or lactate threshold testing, could provide a more comprehensive understanding of the physiological and tactical adaptations induced by SSG and HIIT (Ouertatani et al., 2022). Our study offers a methodological innovation through the structured progression of both training interventions, systematically manipulating variables such as

player numbers, spatial dimensions, work-to-rest ratios, and exercise intensity. This progressive approach represents a departure from many previous studies that employed static training parameters throughout the intervention period. By documenting both the acute and cumulative effects of this progressive overload model specifically tailored for adolescent hockey players, our research provides novel insights into age-appropriate training prescription that respects biological development while maximizing training adaptations.

Furthermore, the study didn't account for the potential injury risks associated with both training types. High intensity training, whether through SSG or HIIT, can increase the risk of overuse injuries, especially in young athletes. Future research should investigate injury rates and recovery patterns to better understand how to balance training intensity with athlete safety. Given that both SSG and HIIT yielded significant improvements, coaches might consider using a hybrid approach that combines the strengths of both methods. For instance, HIIT could be used to build foundational anaerobic capacity, while SSG could be incorporated to enhance sport-specific skills and tactical awareness. Periodization of training is also key; coaches should gradually increase the intensity, volume, and complexity of SSG sessions to maximize physiological and tactical benefits. Variables like player numbers, field size, and game duration can be adjusted to keep the training challenging and engaging (Arslan et al., 2020). Additionally, monitoring tools like heart rate trackers and perceived exertion scales can help tailor training intensities to individual athletes' needs. This is especially important for youth players, who may have varying levels of physical and tactical development. Finally, since SSG is generally perceived as more enjoyable than HIIT (Selmi et al., 2020), incorporating game-like scenarios and competitive elements into training sessions could boost motivation and engagement. This is crucial for long-term athlete development, as enjoyment often plays a big role in keeping young players committed to the sport.

Conclusions

The results of this study confirm that both SSG and HIIT effectively improve anaerobic endurance in youth hockey players, with SSG providing slightly superior benefits. These findings align with existing research across multiple team sports, reinforcing the role of SSG in developing both anaerobic performance and sport-specific skills. While HIIT remains an effective method for conditioning, the integration of SSG into training programs may provide additional benefits in motivation, technical proficiency, and decision-making. Future studies should explore long-term adaptations, injury risk, and the potential effects of combining both methods in hockey training.

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Conflict of Interest

The authors declare no conflict of interest in relation to this study.

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З'ясування впливу ігор неповними складами та методу високоінтенсивного інтервального тренування на анаеробну витривалість у хокеїстів підліткового віку

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

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Історія питання. Враховуючи складні аеробні й анаеробні навантаження в спорті, оптимізація тренувальних методологій має вирішальне значення для покращення здатності гравців до повторних спринтерських забігів, підтримання

зусиль впродовж матчів та підвищення загальної результативності. Попри те, що хокей потребує від гравців значної анаеробної потужності для виконання вибухових рухів і спринтерських забігів, переривчастий характер гри також висуває суттєві вимоги до аеробних систем задля відновлення організму між високоінтенсивними діями.

Мета дослідження. Метою цього дослідження було оцінити та порівняти ефективність використання ігор невеликими складами (ІНС) та методу високоінтенсивного інтервального тренування (ВІІТ) щодо підвищення анаеробної витривалості серед хокеїстів на траві підліткового віку.

Матеріали та методи. У дослідженні взяли участь 36 юнаків-хокеїстів (віком 15-17 років), яких було розподілено за методом рандомізації на три групи: ІНС (n=12), ВІІТ (n=12) та група активного контролю (ГАК) (n=12). Інтервенція тривала шість тижнів, кожна група тренувалася тричі на тиждень відповідно до свого режиму тренувань. Оцінювання рівня анаеробної витривалості проводилось за допомогою тесту анаеробного спринту на основі бігу (Running-Based Anaerobic Sprint Test, RAST) на перед- і постінтервенційному етапах дослідження. З метою аналізу взаємодії між часом (претест і посттест) та груповим розподілом проведено двофакторний змішаний дисперсійний аналіз.

Результати. В обох групах (ІНС та ВІІТ) спостерігалось значне поліпшення показників анаеробної витривалості порівняно з групою ГАК. Група ІНС продемонструвала істотніше зниження показників RAST (5.03%), ніж група ВІІТ (3.71%). Статистичний аналіз виявив суттєвий основний вплив часу та групи ($F = 14.80$, $p < 0.001$, $\eta^2p = 0.47$), що вказує на значущий вплив обох інтервенцій. Проведення *post hoc* порівнянь показало, що група ІНС перевершила групу ВІІТ, однак обидві групи значно покращили рівень анаеробної витривалості порівняно з контрольною групою.

Висновки. У цьому дослідженні підтверджено ефективність використання як ІНС, так і ВІІТ щодо підвищення анаеробної витривалості у хокеїстів-підлітків, причому в ІНС спостерігається незначна перевага. Результати дослідження свідчать про те, що інтеграція вправ, специфічних для певного виду спорту, як показано в ІНС, може призвести до суттєвіших фізіологічних і тактичних покращень, ніж застосування традиційних протоколів ВІІТ. Необхідно провести подальші дослідження з метою вивчення довгострокових адаптаційних процесів, ризику травмування та потенційних переваг поєднання обох методів тренувань для оптимального підвищення результативності.

Ключові слова: анаеробна витривалість, спортсмени-підлітки, хокей на траві, здатність до повторного спринту.

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The Impact of Competitive Regulatory Changes on Psychological Indicators Ensuring the Efficiency of a Wrestler's Performance

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Abstract

Background. The study attempts to reveal those psychological leading indicators that have emerged as a consequence of the recent regulatory changes in wrestling, which can ensure stable and high competitive results.

Objectives. This study aimed to identify the primary psychological factors that ensure the stability of a wrestler's high competitive results and to characterize the specifics of their manifestations, as influenced by the regulatory requirements.

Materials and methods. To organize the research process more effectively, modern advanced sensory technologies, tests, questionnaires, observations, and mathematical statistical methods were used. All of these techniques have proven to be of practical significance in sports psychology. The study was conducted among 33 highly qualified wrestlers from the national team of the Republic of Armenia (winners and medalists of World, European, and International Competitions).

Results. The comparative analysis of the research results revealed the leading psychological indicators that ensure the effectiveness of wrestlers' competitive performance under previous and current regulatory requirements. The study also interpreted the reliable interrelationships of these indicators with mental states, various stress factors, individual personality traits, and psychomotor abilities.

Conclusions. In modern wrestling, the effectiveness of technical and tactical preparation is realized through the patterns of interconnected manifestations of psychomotor indicators, whereas in the past, manifestations of the emotional sphere prevailed, which have undergone significant transformations over the years due to regulatory changes.

Keywords: regulatory changes, intercorrelation connections, psychomotor abilities, comparative analyses.

Introduction

The continuous structural and regulatory changes in competitive activities introduce new requirements for professionals in almost all sports fields (Arias et al., 2011; Pluta et al., 2014; Janowski et al., 2020), including coaches, educators, sports doctors, psychologists, and others (Li & Hopkins, 2022; Rennie et al., 2024).

Wrestling is among the sports that undergo regulatory changes from one Olympic Games to the next. These changes not only pose new challenges for the wrestler's competitive style, tactics, and strategy but also introduce new psychological challenges for athletes in international competitions (Geghamyan, 2018).

The most significant regulatory changes in wrestling were introduced by the International Wrestling Federation in 2013 (United World Wrestling. Official Website) and are still ongoing to this day. Significant changes have been made to weight categories, the overall duration of matches and competitions, and the draw system. Under the new regulations, mandatory leg clinches in freestyle wrestling, determined by the draw, have been eliminated, as well as the kneeling position work in Greco-Roman wrestling. New regulations have been introduced, including an increase in the total duration of matches and competitions, changes in the scoring system for techniques, adjustments to the timing of athlete weighings, and many other similar modifications (Matthew et al., 2005; Tünnemann, 2013; Korobeynikov et al., 2016).

The aforementioned regulatory changes, along with the increased intensity of participation in competitions,

the expanded volume of training loads, and other factors in recent years, have introduced new psychological challenges for wrestlers (Ahmed Abdo Hassan Abdel Wareth, 2022; Farzizadeh & Abravesh, 2022; Mousavi et al., 2023). These challenges require the effective distribution of physical and mental resources, an acute sense of time perception, mobilization readiness, functional abilities for rapid and efficient recovery, a specialized level of development in musculoskeletal sensations, a high degree of development in sensorimotor reactions, exceptional stability to external and internal stress factors, strong willpower, competitive psychological reliability, and more (Rutkowska & Gierczuk, 2017; Rutkowska, Gierczuk, & Buszta, 2020; Ranjbar et al., 2023). Due to all this, despite many years of experiments and research, the previously studied and developed psychological indicators that ensure the effectiveness of a wrestler's competitive activity are not justified under current conditions (Eklund, Gould, & Jackson, 1993; Bernthal & Medway, 2005; Geghamyan, 2016), and this issue has not yet been finally clarified and needs to be continuously improved in the ways of its implementation (Cieřliński, Gierczuk, & Sadowski, 2021; Korobeynikov, 2022).

Thus, the problem of revealing the psychological foundations of the effectiveness of a wrestler's competitive activity is one of the primary requirements of psychological science and sports psychology, as it is one of the main guarantees of achieving high results in sports.

Research hypothesis: It is assumed that the psychological indicators of competitive performance efficiency in wrestling are significantly linked to the regulations adopted by the International Wrestling Federation. As these regulations change, they in turn evolve and introduce new demands on the wrestler's readiness and psychological state.

The study purpose: To identify the primary mental factors that ensure the stability of a wrestler's high competitive results and to characterize the specific ways these factors manifest, influenced by the regulatory requirements.

Materials and Methods

Study Participants

The research included 33 highly qualified wrestlers from the national team of the Republic of Armenia (winners and medalists of World, European, and international competitions).

Study Organization

The research was carried out in 2023-2024, in the Chair of Sports Pedagogy and Psychology of Armenian State Institute of Physical Culture and Sport and in the scientific research laboratories of the Institute "Sport EMI". The research process adhered to the requirements of the Helsinki Declaration, and the results were approved by the Ethics Committee of Armenian State Institute of Physical Culture and Sport.

The research focused on studying the indicators of wrestlers' mental phenomena (mental processes, emotional states, personal and psychomotor abilities, etc.) that (Gould, Eklund, & Jackson, 1992; Ahmet İslam, 2022; Matkarimov et al., 2024), according to several authors, can serve as key and leading factors in achieving high competitive

performance (Fuentes et al., 2020; Dominic Malcolm et al., 2023; Poghosyan et al. 2024).

In 2012-2014 based on the results of the research, a comparative and correlational analysis of the psychological indicators of the highly qualified wrestlers, who participated in competitions under the previous regulations, was carried out by us.

The following methods were included in the research process:

1. In the laboratory-instrumental studies, reactionometry equipment was used, allowing for the assessment of indicators of simple, complex, and motor reactions to moving objects. The emotional-volitional domain indicators of the wrestlers were diagnosed using methods of electrodermal resistance and tremometry. Indicators of movement tempo self-regulation and mobilization readiness were assessed through the tapping test.
2. Non-instrumental methods were implemented based on the following:
 - V. E. Milman's questionnaires on "Competitive Mental Reliability" and "Pre-Competition Mental States Diagnosis,"
 - The Khanin-Spielberger Anxiety Self-Assessment Scale,
 - Eysenck's Personality Inventory (EPI version),
 - L. P. Ponomarenko and R. V. Belousova's "Assessment of Personality Stress Resistance" test,
 - R. Lazarus's "Coping Strategies" questionnaire,
 - N. Hall's "Emotional Intelligence" questionnaire,
3. Mathematical statistical methods: The processing of numerical data was carried out using the StatPlus Pro software. This was aimed at the comparative and correlational analysis of indicators related to wrestlers' mental readiness, as well as the analysis of factor indicators. Based on the results, psychological profiles were developed.

Statistical Analysis

Overall, more than 60 psychological indicators of wrestlers were studied. From the multitude of obtained indicators, those with the most reliable and direct correlations were selected. These indicators held central positions within the system of all the studied variables due to their significance.

Among the presented factors, the indicators primarily included those with a factor weight of $r = 0.40$ or higher.

Results

Through research, an attempt was made to conduct a comparative analysis of the leading psychological indicators that ensure the effectiveness of wrestlers' competitive performance under the conditions of former and current regulatory requirements. The goal was to identify and interpret their reliable correlational relationships with mental states, various stress factors, personal characteristics, and psychomotor abilities (See Figures 1 and 2).

The results of previous research, presented in Figure 1 (Geghamyan, V., 2016), indicate that the following demonstrated the most numerous and strongest correlational relationships:

The indicator of competitive emotional endurance, which ensures “mental freshness” during training and competitive processes. This mental freshness serves as a foundation for the effective functioning of not only other mental phenomena but also for the manifestation of physical, technical, and tactical readiness, as well as the organism’s full reserve energy and capabilities.

The indicator of internally meaningful stressors, which is reflected in the wrestler’s fears and doubts. These are associated with concerns about effectively demonstrating readiness when needed, losing points, sustaining injuries, failing to meet the expectations of the coach and teammates, or having their personal initiatives fail. Such stressors lower the wrestler’s confidence in their own abilities.

These indicators have reliable correlational relationships not only with each other but also with personal psychological characteristics, mental states, and psychomotor abilities. This provides a basis for considering that these two indicators, along with those correlated with them, were previously the leading and primary indicators in wrestling.

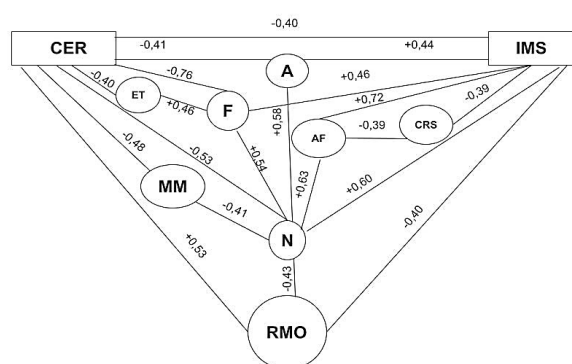


Fig. 1. Reliable correlational relationships among the studied indicators prior to the 2013 regulatory changes (Geghamyan V., 2016). Note: □ – Leading indicators; O – Main indicators. Competitive Emotional Resilience (CER), internally meaningful stressor (IMS), Pre-Competition Apathy (A), Pre-Competition Fever (F), Personal Anxiety (PA), Combat Readiness State (CRS), Emotional Tension (ET), Neuroticism (N), Reaction to a Moving Object (RMO), Simple Motor Reaction (SMR), Maximum Mobilization (MM)

The analysis of the correlational relationships of the above-mentioned leading indicators also demonstrates that, previously, certain personal factors predominantly occupied positions within the internal mechanisms of the correlational structure. These included emotional stability based on temperament type and the indicator of personal anxiety. However, indicators of mental state manifestations, such as pre-competition fever, apathy, and emotional stability, prevailed. Among psychomotor abilities, only the indicators of reaction to a moving object and mobilization ability were incorporated into the internal structure of the correlational relationships.

The analysis of the results from the research carried out after the latest regulatory changes reveals that the picture has significantly changed (see Figure 2).

Thus, the indicator of Competitive Emotional Resilience (CER) has demonstrated direct reliable correlations with several factors: Complex Motor Reaction (CMR, $r = -0.58$),

Emotional Tension (ET, $r = -0.61$), Control of Movement Tempo (CMT, $r = -0.42$), Reaction to a Moving Object (RMO, $r = +0.81$), and Emotional Intelligence (EI, $r = -0.53$) (see Figure 2).

As we can observe, this indicator has shown the most numerous and strongest correlational relationships with the indicators of psychomotor abilities. Such correlations are justified, as the latest regulatory changes in wrestling have specifically impacted the overall duration of matches, thereby increasing the intensity of the matches. Under time-limited conditions, the wrestler must solve the tasks set before him, be able to implement tactical plans, demonstrate activity to avoid penalties, and so on. Wrestlers with different competitive styles handle this in various ways. For instance, many wrestlers perform tactical actions at the very end of the match, within the last 10 seconds, while others show activity at the beginning of the match, scoring points early and then attempting to maintain their advantage until the end. All of this places new demands on the wrestler, particularly regarding their time perception, mobilization readiness, and motor reaction.

The indicator of Internally Meaningful Stressors (IMS), unlike previously, has shown relatively fewer correlations with Complex Motor Reaction (CMR, $r = +0.49$), Stress Resistance (SR, $r = -0.77$), and the Number of Errors in Complex Motor Reaction (CMR-Errors, $r = -0.50$). Interestingly, no direct reliable correlational relationship was observed with the Emotional Resilience (CER) indicator. These correlations were mediated through the indicators of Complex Motor Reaction (CMR).

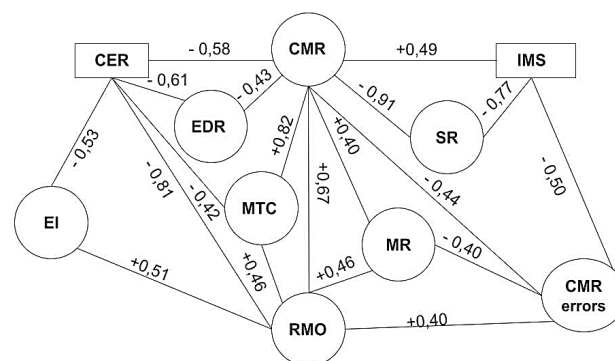


Fig. 2. Reliable correlational relationships among the studied indicators following the regulatory changes in wrestling competition. Note: □ – Leading indicators; O – Main indicators. Competitive emotional resilience (CER), internally meaningful stressor (IMS), complex motor reaction (CMR), reaction to a moving object (RMO), emotional intelligence (EI), stress resistance (SR), mobilization readiness (MR), movement tempo control (MTC), number of errors in complex motor reaction (CMR-errors), electrodermal resistance (EDR)

The analysis of these correlations indicates that a significantly high presence of internally meaningful stressors (IMS) in a wrestler leads to a decrease in the accuracy and speed of performing complex motor actions, as well as the manifestation of technical errors in both simple and complex situations. This, in turn, can result in anxiety manifestations of behavior and a state of excessive emotional tension.

Discussion

The research hypothesis suggested that psychological indicators of competitive performance efficiency in wrestling are significantly linked to regulations adopted by the International Wrestling Federation. As these regulations change, the psychological indicators evolve and introduce new demands on the wrestler's readiness and psychological state. Our research results confirm this hypothesis, showing that after the regulatory changes in 2013, the structural mechanisms of wrestlers' psychological indicators have significantly changed. Specifically, psychomotor ability indicators have gained a more central role in the psychological readiness structure of wrestlers, in contrast to the past when emotional domain indicators were predominant.

The analysis of our research results reveals several important shifts in the psychological readiness structure of wrestlers that directly align with research discussed in the introduction. For example, our findings on the impact of competitive regulations on psychological indicators are consistent with Arias et al. (2011), who noted that regulatory changes create new requirements in almost all sports. Similarly, Pluta et al. (2014) and Janowski et al. (2020) also revealed adaptations in athletes in response to regulatory changes, which aligns with our results.

The general patterns of competitive duels noted in Korobeynikov et al. (2016) work are confirmed by our research, particularly the assertion that regulatory changes dictate changes in technical and tactical preparation mechanisms. However, our work extends this view by revealing that psychomotor ability indicators have become key components of this mechanism, which was not specified in Korobeynikov's work.

Rutkowska and Gierczuk's (2017; 2020) studies emphasized the importance of psychological factors in wrestling, which is further confirmed by our research. In their work, however, the role of psychomotor abilities was not emphasized, which is one of the important discoveries of our research.

Ranjbar et al. (2023) work, which links mental toughness with motor learning in wrestling, is supported by our results, which show that complex motor reaction indicators and movement tempo control are closely related to competitive emotional resilience. Mousavi et al. (2023) studied the effect of interventions on symptoms of stress and depression in wrestlers, which complements our discovered connection between internally meaningful stressors and stress resistance.

Our research also confirms the conclusions of Gould, Eklund, and Jackson's (1992) classic study on the mental preparation of wrestlers, but our work shows that under modern regulatory conditions, the importance of psychological indicators has shifted towards the psychomotor domain.

Our study results have several practical applications that can be useful for coaches, sports psychologists, and wrestlers. First, our findings suggest that in modern wrestling, the preparation process should be reoriented towards the development of psychomotor abilities.

Given that complex motor reaction, reaction to a moving object, and movement tempo control indicators are key indicators in modern wrestling, coaches should provide specific exercises to develop these abilities. For example,

training processes could include exercises that develop wrestlers' ability to quickly respond to opponent movements, feints, and attacks. These exercises may include working at different speeds, responses in unexpected situations, and performing technical actions under time-constrained conditions.

We suggest that sports psychologists develop new models of psychological interventions aimed not only at emotional stability but also at improving psychomotor abilities. In particular, mental training can be applied to help wrestlers improve their time perception, mobilization readiness, and motor reaction.

It is important for wrestlers to realize that in modern regulatory conditions, competitive effectiveness depends not only on technical skills and physical fitness but also on a high level of psychomotor abilities. Therefore, they should pay attention to the development of this area in their individual training.

The importance of our research results is not limited to theoretical value alone. First, this work illuminates the fundamental changes that have occurred in wrestling following recent regulatory changes, which is important for coaches and athletes to effectively plan their training process.

Second, our findings that psychomotor ability indicators have become leading factors in ensuring competitive effectiveness help reorient traditional approaches to wrestler preparation, which were predominantly focused on emotional stability.

Third, our discovered correlational relationships between competitive emotional resilience, internally meaningful stressors, and psychomotor abilities shed new light on the structure of wrestlers' psychological readiness, which can help develop more targeted and effective psychological preparation methods.

Fourth, our research shows that regulatory changes in sports can lead not only to technical and tactical changes but also to fundamental psychological shifts, which is important for sports regulators and managers.

Fifth, the results of our work may be useful not only for wrestling but also for other martial arts and combat sports that have similar requirements for psychomotor abilities.

Based on our research results, several directions for further studies can be proposed.

First, it would be valuable to conduct longitudinal studies that follow wrestlers' psychological adaptation to regulatory changes. Such studies would help understand how wrestlers adapt to new rules over time and what psychological mechanisms they develop.

Second, training methods specifically aimed at developing psychomotor abilities in wrestlers could be developed and tested. Evaluating the effectiveness of these methods could help improve the preparation process for wrestlers.

Third, it would be interesting to conduct cross-cultural comparisons of wrestlers' psychological readiness in different countries and wrestling schools. Such studies would help reveal whether there are cultural peculiarities in psychological adaptation.

Fourth, the impact of changes in psychological indicators on wrestlers' choice of technical and tactical actions could be studied. Such research would help understand how psychological factors affect wrestlers' decision-making process during competition.

Fifth, it would be valuable to study the peculiarities of psychological readiness of wrestlers in different age groups under modern regulatory conditions, which would help develop training methods appropriate to age characteristics.

Thus, our research not only reveals changes in the role of psychological indicators in modern wrestling but also opens new horizons for further studies that can contribute to the development of wrestling and improvement of athlete preparation.

Conclusions

The data obtained from the studies conducted before and after the recent regulatory changes in wrestling led to the conclusion that the new manifestations and significance of the correlational relationships among the studied psychological leading indicators have become more emphasized. This was not expressed or substantiated in the field of wrestler readiness in previous research.

Although similar correlations were observed in the past, they were predominantly characterized by manifestations of the emotional domain. In modern wrestling, however, the effectiveness of technical and tactical readiness is realized through the interrelated manifestations of psychomotor indicators. This is clearly evidenced by the research results.

The entirety of the presented correlations also indicates that continuous processes are occurring within the psyche of wrestlers, which can later acquire a qualitatively new nature. These processes have the potential to enhance the effectiveness of competitive performance and lead to the achievement of new results, provided no new regulatory changes are introduced.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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Вплив регуляторних змін у змагальній діяльності на психологічні показники, що забезпечують ефективність виступу борця

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 7 с., 2 рис., 26 джерел.

Історія питання. У дослідженні здійснено спробу виявити ті психологічні випереджаючі індикатори, поява яких зумовлена нещодавніми регуляторними змінами у спортивній боротьбі, що можуть забезпечити стабільні та високі змагальні результати.

Мета дослідження. Це дослідження мало на меті визначити основні психологічні чинники, що забезпечують стабільність високих змагальних результатів борця, і охарактеризувати специфіку їх проявів залежно від впливу регуляторних вимог.

Матеріали та методи. Задля ефективнішої організації дослідницького процесу використовувалися сучасні прогресивні сенсорні технології, тести, опитувальники, обсерваційні та математико-статистичні методи. Доведена практична значущість усіх зазначених методик в галузі спортивної психології. Дослідження проведено серед 33 висококваліфікованих борців національної збірної Республіки Вірменія (переможці та призери світових, європейських та міжнародних змагань).

Результати. Порівняльний аналіз результатів дослідження встановив провідні психологічні індикатори, що забезпечують ефективність змагальної діяльності борців відповідно до попередніх та поточних регуляторних вимог. У дослідженні також інтерпретовано достовірні взаємозв'язки цих показників із психічними станами, різними стресовими факторами, індивідуальними рисами особистості та психомоторними здібностями.

Висновки. У сучасній спортивній боротьбі ефективність техніко-тактичної підготовки реалізується через закономірності взаємопов'язаних проявів психомоторних показників, тоді як раніше переважали прояви емоційної сфери, які з роками зазнали значних трансформацій внаслідок регуляторних змін.

Ключові слова: регуляторні зміни, міжкореляційні зв'язки, психомоторні здібності, порівняльні аналізи.

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Study of the Factor Structure of Motor Fitness in 8-Year-Old Boys During the Process of Mastering the “Kin Geri” Kick Technique

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Abstract

Objectives. The research aims to identify the factor structure of motor fitness in 8-year-old boys during the process of mastering the “Kin geri” front kick technique.

Materials and methods. Thirty-two 8-year-old boys participated in the study. Both the children and their parents were informed about the nature of the research and provided written consent for participation. Participants were assured of their right to withdraw from the study at any time without explanation. All procedures were conducted following the Declaration of Helsinki. The following research methods were employed: analysis of scientific and methodological literature, pedagogical observation, timing of educational tasks, motor fitness testing, and statistical data analysis.

Results. Factor analysis identified six factors accounting for 73.98 % of the total variance. The largest contribution (24.87 %) to the total variance of the sample was made by the factor “special complex coordination preparedness”. The second most significant factor was the “level of special motor fitness” (15.71 %). Other identified factors included “physical development” (12.74 %), “coordination of movements” (9.04 %), “agility” (6.05 %), and “flexibility” (5.58 %). Since the “Kin geri” kick is executed below belt level (“Gedan” level), the contribution of flexibility is minimal and may be considered less relevant. During the training of the “Kin geri” front kick, the most influential elements include anthropometrical indicators, speed of integral movements, special coordination fitness, balance, static strength, general endurance, and the degree of technical mastery of the “Kin geri” front kick demonstrated through a series of training tasks.

Conclusions. The analysis of the factor structure of motor fitness provides essential data for optimizing the training process of the “Kin geri” front kick in 8-year-old karate athletes. The findings highlight the integrity of motor skill formation and the development of motor abilities. A significant outcome of the factor analysis is the establishment of a foundation for designing effective training programs tailored to the physical development and motor fitness level of children and adolescents.

Keywords: factor analysis, 8-year-old boys, fitness structure, Kyokushinkai karate, “Kin geri” kick.

Introduction

In recent years, numerous studies have highlighted the importance of creating a safe and motivating environment for children to acquire sport-specific knowledge and skills (Pavlova, Bodnar & Vitos, 2018; Rodrigues & Antunes, 2019; Pinto-Escalona, Gobbi, Valenzuela et al., 2024). These authors emphasise the importance of maximising the engagement of prepubertal and pubertal students in sports activities. According to Ma & Qu (2017), Antunes, Rodrigues & Kirk (2021), initiating martial arts training provides a positive sporting experience and contributes to children's physical,

intellectual, and spiritual development. Emphasis on karate training, as noted by Harwood-Gross, Lambez, Feldman et al. (2021), Pinto-Escalona, Valenzuela, Martin-Loeches et al. (2022), appears to be a promising alternative for enhancing learning and behavioural outcomes in children facing significant psychosocial challenges and low academic achievement.

Among the key factors contributing to high performance in martial arts, researchers identify morphological characteristics as particularly important (Rakita, Rakonjac, Vukadinović-Jurišić & Obradović, 2018). Long-term training is known to influence body composition and overall physical development (Carlisle, Weaver, Stodden et al., 2019; Drenowatz, Greier, Ruedl et al., 2019; Kolunsarka, Stodden, Gråstèn et al., 2024).

Experts have analysed how different levels and types of sports specialisation affect the morphological parameters of athletes across various environments. Chen, Chen, Liu et al. (2022) demonstrated a correlation between body mass index and physical fitness in children and adolescents. Similarly, den Uil, Janssen, Busch et al. (2023) examined how weight status, physical fitness, and motor competence vary with age. Their findings support the view that physically fit children from an early age tend to be more proficient in executing motor skills and are generally more active.

Barnett, Webster, Hulteen et al. (2022) reported insufficient evidence for a direct link between overall physical fitness and general motor competence. However, they found strong evidence supporting a reciprocal causal relationship between physical fitness and motor competence in specific domains such as locomotion, coordination, and balance.

Studies by Rakita, Rakonjac, Vukadinović-Jurišić et al. (2018), Kahrović, Jovanović, Murić et al. (2018), Marchenko, Ivashchenko, Jagiello et al. (2024), and others have demonstrated a strong correlation between physical fitness and motor awareness in children practicing Shotokan and Kyokushinkai karate.

Given that Kyokushinkai karate requires the development and expression of diverse motor abilities (speed, agility, power, anaerobic capacity, etc.), researchers often recommend the use of comprehensive test batteries to assess athletes' motor fitness (Styriak, Billman & Augustovicova, 2020; Marchenko & Verdysh, 2021; Marchenko, Ivashchenko & Khudolii, 2023). These control tests should reflect the specific biomechanical patterns of movement relevant to the sport. The athlete's level of training is a critical consideration. Tests designed for highly skilled or well-conditioned athletes may not be appropriate for beginners, whose performance may be limited by technical deficiencies or insufficient conditioning. In addition, factors such as gender and age must also be considered (Ghadiri, O'Brien, Soltani et al., 2022; Marchenko, Ivashchenko, Jagiello et al., 2022; Marchenko, Ivashchenko, Khudolii & Verygin, 2024).

The analysis of primary test results in assessing motor fitness provides only indirect information about its actual state. Many of the measured parameters are correlated to varying degrees, which leads to redundancy and informational overlap. Therefore, it becomes necessary to transform large datasets into a more compact and interpretable form to better represent motor fitness development dynamics and general patterns in young karate athletes during the prepubertal period.

The research aims to identify the factor structure of motor fitness in 8-year-old boys during the process of mastering the "Kin geri" front kick technique.

Materials and methods

Study participants

Thirty-two 8-year-old boys participated in the study. Both the children and their parents were informed about the nature of the research and provided written consent for participation. Participants were assured of their right to withdraw from the study at any time without explanation.

All procedures were conducted following the Declaration of Helsinki.

Study Design

The following research methods were employed: analysis of scientific and methodological literature, pedagogical observation, timing of educational tasks, motor fitness testing, and statistical data analysis.

The testing programme included validated assessments that covered the following components:

- anthropometric indicators: body weight, body length, chest circumference, and lung capacity;
- general motor fitness indicators: 30 m run from a high start, 4x9 m shuttle run, coordination exercises involving combined movements of the arm, torso and legs; one-legged stance with eyes closed, walking in a straight line after 5 turns, standing long jump, dynamometry of the right and left arms, flexion and extension of the arms while hanging on a rope, 300 m run, and seated trunk forward flexion.
- exercises to assess special speed and coordination skills in karate athletes: "touch evasion test" exercise; execution of "Kin geri" front kicks on rackets with a partner, zigzag run around cones ("snake" drill); and "comprehensive test". These tests were adapted from classical boxing and martial arts (Slovensky zvez karate, 2017; Styriak, Billman & Augustovicova, 2020; Marchenko & Verdysh, 2021).

The "Touch evasion test" was performed in pairs. One participant attempted to touch specific permitted target areas on the opponent's body (head, shoulders, chest, abdomen) using open palms. The second participant executed only defensive action, maintaining stance, retreating, and covering the torso with the elbows, without delivering counterattacks. The exercise lasted for 15 s, and the number of touches received by the defending participant was recorded.

The "Speed front kicks "Kin geri" on rackets with a partner performing zigzag run around cones" test was conducted on a tatami measuring 8x3 m². Three cones were placed in a straight line: the first cone was positioned 2 m from the starting line, and the remaining two were spaced equidistantly at the same distance from each other. The subject started at the designated line alongside an assistant holding two striking targets (rackets). At the signal, the participant progressed through the cone arrangement using a snake-like pattern, performing "Kin geri" front kicks alternately while covering the 8-meter distance. Timing stopped once the participant fully crossed the finish line. The outcome of the test was calculated using the Efficiency Coefficient, defined as the ratio of the number of successful kicks to the total time taken to complete the distance (C_{eff}).

The "Comprehensive test" was modified to align with the technical focus of the study. It incorporated core karate techniques (4 "Tsuki chudan" hand strikes and 4 "Kin geri" front kicks). The test was conducted on a 7x7 m tatami. At a sound signal, the participant began in a sitting position on the floor, legs extended, with heels on the starting line. After the start, the participant runs around the cone, then continues to run backward, after he runs around four cones in a "snake" style, executing four hand strikes and four kicks; performing ten jumps over low barriers 10-12 cm (5

on one leg in one direction and 5 on the other leg in the reverse direction). In the final stage, the participant transfers tennis balls from one plastic plate to another. The stopwatch stopped when the participant placed the last tennis ball on the finish plate.

In the course of the research the results of the programmed training process for mastering the “Kin geri” front kick technique were recorded based on task decomposition: series 1 “Physical fitness”, series 2 “Execution of initial and final positions”, series 3 “Mastery of key movements essential for performing the exercise”, series 4 “Ability to control movements”, series 5 “Mastery of leading exercises”, series 6 “Mastery of leading exercises” (Marchenko, Khudolii, Ivashchenko & Musliumova, 2023; Marchenko, Ivashchenko, Jagiello et al., 2023). Testing was conducted using a competitive method.

Statistical Analysis

Data were collected and systematised using Microsoft Excel 2016 (Microsoft Corp., Redmond, WA, USA). Statistical analysis was performed using IBM SPSS Statistics for Windows, Version 26.0 (IBM Corp., Armonk, NY, USA). Factor analysis was employed to summarise the variables and group them according to their characteristic relationships, helping to determine the role of the learning process within the overall training structure.

During the factor analysis, the following indicators were calculated and analysed: Bartlett’s test of sphericity and the Kaiser-Meyer-Olkin (KMO) test of sampling adequacy. Factors were extracted using the principal component analysis (PCA) method, and factor rotation was carried out using the Varimax method with Kaiser normalization.

Results

To determine the role of the learning process for the “Kin geri” front kick within the overall training structure of 8-year-old boys, a factor analysis was conducted (Tables 1-4). Table 1 presents the results of motor fitness testing in this age group. An analysis of the coefficients of variation (V, %) revealed that the motor fitness of young karate athletes was homogeneous in most tests: No. 1 “Body weight, kg” (21.4 %); No. 2 “Body length, cm” (4.1 %); No. 3 “Chest circumference, cm” (8.3 %); No. 4 “Lung capacity, m3” (13.2 %); No. 5 “30 m run, s” (10.5 %); No. 6 “touch evasion test, number of missed touches” (28.9 %); No. 7 “Speed front kicks Kin geri, C_{eff} ” (11.5 %); No. 8 “4x9 m shuttle run, s” (6.5 %); No. 9 “Coordination test (arm, torso, and leg movement combination), points” (4.0 %); No. 11 “Walking in a straight line after 5 turns, deviation in cm” (8.1 %); No. 12 “Comprehensive test, s” (8.8 %); No. 13 “Standing long jump, cm” (10.4 %); No. 14 “Dynamometry of the right hand, kg” (25.8 %); No. 15 “Dynamometry of the right hand, kg”

Table 1. Results of motor fitness testing of 8-year-old boys

Nº	Tests	X	S	m	V, %
1	Body weight, kg	27.506	1.038	5.875	21.4
2	Body length, cm	127.344	0.934	5.283	4.1
3	Chest circumference, cm	62.703	0.920	5.204	8.3
4	Lung capacity, m3	1506.875	35.062	198.339	13.2
5	30 m run, s	7.203	0.134	0.759	10.5
6	Touch evasion test, number of missed touches	7.156	0.365	2.065	28.9
7	Speed front kicks “Kin geri”, C_{eff}	1.496	0.030	0.172	11.5
8	4x9 m shuttle run, s	13.719	0.158	0.893	6.5
9	Exercises to combine movements of arms, body, legs, points	8.875	0.064	0.359	4.0
10	One-legged stand with eyes closed, s	4.031	0.303	1.713	42.5
11	Walking in a straight line after 5 turns, deviation in cm	127.063	1.808	10.229	8.1
12	Comprehensive test, s	25.232	0.393	2.223	8.8
13	Standing long jump, cm	117.250	2.153	12.181	10.4
14	Dynamometry of the right arm, kg	10.906	0.497	2.810	25.8
15	Dynamometry of the left arm, kg	9.938	0.419	2.368	23.8
16	Flexion and extension of the arms while hanging on a rope, repetitions	5.50	0.554	3.132	56.9
17	300 m run, s	110.25	2.919	16.512	15.0
18	Seated trunk forward flexion, cm	-1.406	0.933	5.278	375.4
19	1 series, assessment	8.928	0.132	0.749	8.4
20	2 series, assessment	7.981	0.107	0.605	7.6
21	3 series, assessment	8.950	0.124	0.70	7.8
22	4 series, assessment	8.050	0.143	0.810	10.1
23	5 series, assessment	8.641	0.155	0.878	10.2
24	6 series, assessment	9.384	0.109	0.614	6.5

(23.8 %); No. 17 “300 m run, s” (15.0 %); No. 19-24 Evaluation of results from programmed training in the “Kin geri” front kick, based on task decomposition (6.5 %-10.2 %).

The results of the tests revealed a heterogeneous level of motor fitness among the boys in the following assessments: No. 10 “One-legged stand with eyes closed, s” (42.5 %); No. 16 “Flexion and extension of the arms while hanging on a rope, repetitions” (56.9 %); No. 18 “Seated trunk forward flexion, cm” (375.4 %). The high coefficients of variation observed in tests “One-legged stand with eyes closed, s”, “Flexion and extension of the arms while hanging on a rope, repetitions” and “Seated trunk forward flexion, cm” indicate that these exercises are particularly difficult to perform.

Overall, the motor fitness level of 8-year-old boys was homogeneous in terms of anthropometric characteristics and physical qualities such as speed, coordination, speed-strength, static strength, endurance, flexibility, and the outcomes of the learning process. However, heterogeneity was observed in the development of arm strength and vestibular stability.

Bartlett's test of sphericity indicated that the data obtained are suitable for factor analysis during the training of the “Kin geri” front kick, with a significance level of $p < 0.05$. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy demonstrated a satisfactory level for applying factor analysis ($KMO = 0.526$; $p > 0.05$) to the sample of 8-year-old boys (Table 2).

Table 2. Checking the appropriateness of factor analysis

KMO and Bartlett's test of sphericity			
The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy	0.526		
	Approximate Chi-square	546.481	
Bartlett's test of sphericity	df	276	
	Significance	0.000	

In the process of factor analysis of the testing data of 8-year-old boys, six factors were identified, explaining 73.98 % of the total variance of the indicators (Table 3). The factor matrix illustrating the structure of physical development, motor fitness, and technical preparedness of 8-year-old boys during the training of the “Kin geri” front kick is presented in Table 4.

The first factor makes the largest contribution to the total variance of the sample (24.87 %). It shows strong correlations

with the results of the following tests: “30 m run” (0.862), “Touch evasion test, number of missed touches” (0.794), “Speed front kicks “Kin geri” (-0.846), “Comprehensive test” (0.883). This factor reflects the manifestation of specific coordination in karate movements and overall movement speed. It is designated as “Special complex coordination preparedness”.

The second factor, which accounts for 15.71 % of the total variance, is identified as a unipolar factor representing the state of technical fitness. It correlates with the results of training in the following series: 1st – “Exercises for the development of motor abilities” (0.763); 2nd – “Starting and ending positions” (0.731); 3rd – “Actions essential for performing the exercise” (0.753); 4th “Training in movement control” (0.759); and 6th – “Overall exercise performance” (0.722). This factor is referred to as “The level of special motor fitness”.

The third factor (explaining 12.74 % of the variance) correlates with anthropometric indicators: “Body weight” (0.921), “Body length” (0.782), and “Chest circumference” (0.933). This factor is labelled “physical development”.

The fourth factor contributes 9.04 % to the total variance and is associated with the test results for “Exercises to combine movements of the arms, body, legs” (0.713) and “One-legged stand with eyes closed” (0.881). It characterises the ability to maintain postural stability and to control movement in static positions. This factor is termed “coordination of movements”.

Factor 5 accounts for 6.05 % of the total variance. It shows the highest correlation with the “4×9 m shuttle run test” (-0.737), which characterises the ability to differentiate spatial and temporal parameters of movement. This factor is referred to as “agility”.

Factor 6 contributes 5.58 % to the total variance. It is most strongly associated with the indicator “Seated trunk forward flexion” (0.757), highlighting the importance of flexibility in the process of mastering kicking technique. This factor is labelled “flexibility”.

The obtained communalities (h^2), presented in Table 4, indicate the proportion of variance in the variables explained by all six factors. The proposed test battery is informative. The most significant indicators for a comprehensive assessment of the learning process structure in 8-year-old boys mastering the “Kin geri” front kick include the results of the following tests: “Body weight” (0.859), “Chest circumference” (0.897), “30 m run” (0.926), “Touch evasion test, number of missed

Table 3. Explanation of aggregate variance

Component	The initial eigenvalues			Extracting the sum of squared loads			Rotation of the sum of squared loads		
	Total	% variance	Total %	Total	% variance	Total %	Total	% variance	Total %
1	5.968	24.87	24.87	5.968	24.87	24.87	4.514	18.8	18.8
2	3.771	15.71	40.58	3.771	15.71	40.58	3.534	14.7	33.5
3	3.056	12.74	53.32	3.056	12.74	53.32	3.322	13.8	47.4
4	2.169	9.04	62.35	2.169	9.04	62.35	2.592	10.8	58.2
5	1.452	6.05	68.40	1.452	6.05	68.40	1.952	8.1	66.3
6	1.338	5.58	73.98	1.338	5.58	73.98	1.839	7.7	74.0

Method of factor extraction: principal component analysis

Table 4. The returned matrix of components

№	Test title	Component						h ²
		1	2	3	4	5	6	
1	Body weight, kg			0.921				0.859
2	Body length, cm			0.782				0.706
3	Chest circumference, cm			0.933				0.897
4	Lung capacity, cm ³			0.357		0.360	0.487	0.607
5	30 m run, s	0.862				-0.337		0.926
6	Touch evasion test, number of missed touches	0.794				0.314		0.838
7	Speed front kicks “Kin geri”, C _{eff}	-0.846						0.826
8	4×9 m shuttle run, s	0.323				-0.737		0.720
9	Exercises to combine movements of arms, body, legs, points				0.713			0.531
10	One-legged stand with eyes closed, s				0.881			0.865
11	Walking in a straight line after 5 turns, deviation in cm	0.545			-0.683	-0.354		0.908
12	Comprehensive test, s	0.883						0.803
13	Standing long jump, cm	-0.671				0.484		0.719
14	Dynamometry of the right hand, kg			0.544			0.639	0.793
15	Dynamometry of the left hand, kg			0.550			0.484	0.619
16	Flexion and extension of the arms while hanging on a rope, repetitions				0.597	0.594		0.732
17	300 m run, s	0.711				-0.392		0.752
18	Seated trunk forward flexion, cm						0.757	0.624
19	1 series, score		0.763					0.667
20	2 series, score		0.731					0.672
21	3 series, score		0.753					0.697
22	4 series, score		0.759					0.622
23	5 series, score		0.654		0.341			0.736
24	6 series, score		0.722					0.635

Method of factor extraction: principal component method

Method of rotation: varimax with Kaiser normalisation

a. The rotation converged in 6 iterations

touches” (0.838), “Speed front kicks “Kin geri” (0.826), “One-legged stand with eyes closed” (0.865), “Walking in a straight line after 5 turns” (0.908), “Comprehensive test” (0.803), “Dynamometry of the right hand” (0.793), “300 m run” (0.752), and training results from the 5th series “Separate parts of the target exercise and leading exercises” (0.736).

Thus, in the factor model describing the physical development, motor, and technical fitness of 8-year-old boys during the process of learning the “Kin geri” front kick, leading roles are played by anthropometric indicators, speed in integrated movements, special coordination preparedness, balance, static strength, general endurance, and the degree of technical mastery achieved across the training task series.

The data presented in Tables 1-4 demonstrate that the factor structure analysis of motor fitness provided essential information for decision-making in the management of the teaching process of the “Kin geri” front kick technique to 8-year-old karate athletes. A key outcome of this analysis is the establishment of a foundation for designing effective training programmes tailored to the physical development and motor preparedness of children and adolescents.

The most important result of the factor analysis in the context of the programmed training of the “Kin geri” kick was the identification of an independent and dominant factor “special complex coordination preparedness”. This finding underlines the necessity for beginners to receive a high level of basic coordination training. Coordination abilities play a critical role in acquiring and refining specific elements of kicking technique and ensuring their consistency. These abilities enable athletes to perform motor actions efficiently under varying conditions and to execute movements under optimal conditions.

It is essential to teach and develop these coordination skills in alignment with the developmental stages of children. Coordination abilities are a decisive success factor in various competitive disciplines of Kyokushinkai Karate, such as Kumite and Kata.

To visually display the sufficiency of extracted factors, a scree plot of eigenvalues (Cattell’s Scree Test) was used (Fig. 1). This graphical representation highlights the point at which the decrease in eigenvalues becomes less pronounced, indicating the most informative factors. Based on this

graph, five key factors were determined to contribute most significantly to the total variance in the data. So, in the educational and training process when mastering the “Kin geri” kick technique, it is important to consider 5 factors: “special complex coordination preparedness”, “level of special motor fitness”, “physical development”, “coordination of movements” and “agility”.

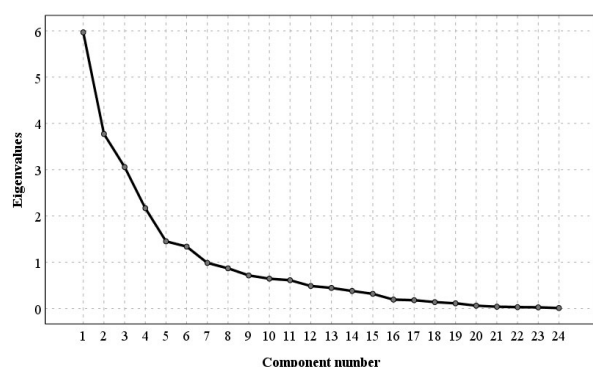


Fig. 1. Graph of eigenvalues

Discussion

The study examined a wide range of indicators aimed at identifying influential factors with prognostic value for planning the teaching process of the kicking technique “Kin geri”. It was assumed that motor skills play a significant role in the motor fitness structure of 8-year-old boys who regularly practice Kyokushinkai karate at the initial training stage. The degree of progressive mastery of exercises accounts for 15.71 % of the variance in test results.

Based on the data analysis, it can be concluded that the development of movement coordination facilitates the formation of motor skills, while physical development serves as a reserve capacity in the process of teaching techniques to 8-year-old boys. This supports and expands upon the findings of Barnett, Webster, Hulteen et al. (2022), Marchenko, Khudolii, Ivashchenko & Musliumova (2023), Marchenko, Ivashchenko, Khudolii & Verygin (2024), who emphasize that the early stages of motor experience acquisition are critical periods during which coordination abilities should be a focal point of training.

Bojkowski, Kalinowski, Śliwowski et al. (2022), Oktarifaldi, Marta, Nugroho et al. (2024), Oktarifaldi, Nopembri, Yudanto et al. (2024), identified a positive and significant relationship between movement coordination and fundamental motor skills. These authors emphasize that enhancing general coordination skills is among the most important factors for achieving educational objectives and recommend incorporating a wide range of coordination-focused exercises into the learning process. In our case, the factors “coordination of movements” and “agility” were identified as components of the motor fitness structure.

The level of special complex coordination preparedness emerged as a general factor in our study, accounting for 24.87 % of the variance in test results. Numerous researchers regard coordination as a cornerstone of motor and sport competence (Bernstein, 1996; Platonov & Nikitenko, 2019; Lyakh, Ambroży, Skripko et al., 2023). The results obtained

from the factor analysis highlight the importance of coordination in acquiring and refining specific karate techniques and ensuring their stability. Coordination enables the effective execution of motor actions under various conditions and contributes to the optimal performance of movements. These findings are consistent with previous research by Ma & Qu (2017), Marchenko, Ivashchenko, Jagiełło et al. (2023), Marchenko, Ivashchenko, Khudolii & Verygin (2024).

We agree with the opinion of Platonov & Nikitenko (2019), Styriak, Billman & Augustovicova (2020), Marchenko & Verdysh (2021) that diagnosing coordination abilities remains a controversial issue. This complexity is further heightened by the fact that athletes from different sports and martial arts styles exhibit distinct dominant coordination abilities, which significantly influence their training and competitive performance. As a result, their evaluation requires the use of specific, complex test tasks and diagnostic technologies that objectively assess the level of special coordination development (Styriak, Billman & Augustovicova, 2020; Marchenko & Verdysh, 2021; Ghadiri, O’Brien, Soltani et al., 2022).

Children’s physical development also contributed 12.74 % to the variation in test scores, underscoring the importance of anthropometric parameters in teaching footwork to young karate athletes. Our findings are in agreement with those of den Uil, Janssen, Busch et al. (2023), who demonstrated a relationship between body mass index, physical activity, and physical fitness at the age of 8 years. However, they diverge from the same authors’ conclusion that anthropometric indicators are unrelated to motor competence at this age, with such associations only becoming evident at the age of 9 years.

The experimental results support the rationale for the organised participation of prepubertal children in sports as a long-term strategy to prevent overweight and obesity (Drenowatz, Greier, Ruedl et al., 2019; Chen, Chen, Liu et al., 2022), and to enhance body mass index, cardiorespiratory fitness, and muscular endurance (Kolunsarka, Stodden, Gråsten et al., 2024).

The influence of morphological features on specific karate skills, as analysed by Rakita, Rakonjac, Vukadinović-Jurišić et al. (2018), indicates that taller karate athletes with a higher percentage of muscle mass achieved better performance in executing the “Mae geri” kick and “Gyaku tsuki” punch techniques. The factor model of motor preparedness in 8-year-old karate athletes, developed in our study, expands on these findings and demonstrates the impact of physical development (chest circumference $h^2=0.933$; body weight $h^2=0.921$; body length $h^2=0.782$) on the effectiveness of learning the “Kin geri” kicking technique.

These results are consistent with the factor analysis findings reported by Rukavytsia, Ivashchenko, Khudolii et al. (2022), Ivashchenko, Berezhna & Cieślicka (2020), which confirm the holistic nature of motor skill formation and motor ability development in children and adolescents. They also provide a basis for identifying future research directions in the instruction of Kyokushinkai karate techniques and the development of appropriate curricula.

Conclusions

The analysis of scientific literature in the field of martial arts has made it possible to identify effective factors that

have been consistently validated over time. Researchers emphasise that the outcomes of sports training are closely interrelated with morphological, functional, and psychological characteristics, levels of physical fitness, as well as the development of both fundamental and specific motor skills, tactical preparedness, and other components. This multitude of factors necessitates a detailed investigation into the structure of motor fitness in 8-year-old boys.

Based on the analysis of empirical data obtained from testing 8-year-old boys, six factors were identified, collectively explaining 73.98 % of the total variance. The most significant contribution (24.87 %) was made by the factor of "special complex coordination preparedness". The next highest contribution (15.71 %) was attributed to "the level of special motor fitness". Additional factors included "physical development" (12.74 %), "coordination of movements" (9.04 %), and "agility" (6.05 %). The factor "flexibility" contributed the least (5.58 %) to the total variance. Since the "Kin geri" kick is executed below the belt level ("Gedan" level), this factor can be neglected.

The analysis of the factor structure of motor fitness yielded valuable insights for managing the training process of teaching the "Kin geri" front kick to 8-year-old karate athletes. One of the key outcomes of the factor analysis is the foundation it provides for developing effective training programs aligned with the physical development and motor fitness levels of children and adolescents.

The findings contribute to enhancing the methodology of teaching Kyokushinkai karate techniques in youth sports schools, clubs, federations, and general education institutions, supporting the effective organization of the educational and training process.

Conflict of Interest

The author declares that she has no conflict of interest.

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Дослідження факторної структури рухової підготовленості хлопців 8 років у процесі оволодіння технікою удару ногою «kin geri»

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 9 с., 2 рис., 26 джерел.

Мета дослідження – визначити факторну модель структури рухової підготовленості хлопців 8 років у процесі оволодіння технікою удару ногою вперед «Kin geri».

Матеріали і методи. У дослідженні взяли участь 32 хлопці 8 років. Діти та їхні батьки були інформовані про всі особливості дослідження та дали згоду на участь в експерименті. Учасників повідомили, що вони можуть вийти з дослідження в будь-який момент без пояснення причини. Усі процедури були виконані відповідно до Гельсінської декларації. Були використані наступні методи дослідження: вивчення та аналіз науково-методичної літератури, педагогічне спостереження, хронометраж навчальних завдань, педагогічний експеримент, методи математичної статистики.

Результати. У процесі факторного аналізу виділилось шість факторів які пояснюють 73,98% сумарної дисперсії показників. Найбільшу величину вкладу (24,87%) в сумарну дисперсію вибірки вносить фактор «спеціальна комплексна координаційна підготовленість». Наступним за величиною вкладу (15,71%) став фактор «рівень спеціальної рухової підготовленості». Визначились також фактори «фізичний розвиток» (12,74%), «координація рухів» (9,04%), «спритність» (6,05%). Частка фактору «гнучкість» від загальної дисперсії найменша (5,58%). Удар «Kin geri» виконується нижче рівня поясу (рівень «Gedan») тому цим фактором можемо знехтувати. У процесі навчання удару ногою вперед «Kin geri» чільне місце займають спеціальна координаційна підготовленість, швидкість в цілісних рухах, загальна витривалість, ступінь оволодіння технікою відповідно серіям навчальних завдань, антропометричні показники, рівновага, статична сила.

Висновки. У результаті аналізу факторної моделі рухової підготовленості отримана необхідна інформація для прийняття рішень під час управління процесом навчання техніки удару ногою вперед «Kin geri» спортсменів-каратистів 8 років. Визначено цілісність процесу формування рухових навичок та розвитку рухових здібностей. Важливим результатом проведеного факторного аналізу слід вважати створення платформи для розробки ефективних навчальних програм відповідно до фізичного розвитку та рівня рухової підготовки дітей і підлітків.

Ключові слова: факторний аналіз, хлопці 8 років, структура рухової підготовленості, Кіокушинкай карате, удар ногою «Kin geri».

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Review Article

Martial Arts and ADHD: A Narrative Review of Cognitive, Behavioral, and Epigenetic Effectse

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Abstract

Objectives. The study aimed to explore the cognitive, behavioral, and potential epigenetic effects of martial arts-based interventions in individuals with Attention-Deficit/Hyperactivity Disorder (ADHD).

Materials and methods. A narrative review was conducted, synthesizing findings from eleven peer-reviewed studies examining martial arts practices — such as taekwondo, judo, karate, kung fu, qigong, and tai chi — in populations diagnosed with ADHD. The focus was placed on executive functions, emotional regulation, and neurobiological mechanisms. Additional literature on physical activity and epigenetic regulation was reviewed to contextualize emerging biological hypotheses.

Results. The findings indicate that martial arts interventions were associated with improvements in attention, working memory, and inhibitory control, particularly in structured disciplines such as judo and taekwondo. Some studies have also reported emotional and behavioral benefits, including reduced impulsivity and improved self-regulation. Although direct epigenetic evidence is lacking, indirect data suggest that physical activity may influence gene expression via mechanisms such as DNA methylation and histone modifications.

Conclusions. Martial arts may support cognitive and behavioral development in individuals with ADHD. Their structured, multimodal nature positions these training practices as promising tools to promote attention and executive functioning. Further research is encouraged to include longitudinal epigenetic profiling to clarify underlying biological mechanisms.

Keywords: ADHD, martial arts, executive functioning, physical activity, behavioral regulation, epigenetics.

Introduction

Attention-Deficit/Hyperactivity Disorder (ADHD) is a common neurodevelopmental condition affecting approximately 5% of children worldwide (American Psychiatric Association, 2022). Characterized by symptoms of inattention, hyperactivity, and impulsivity, ADHD is often associated with executive function deficits, emotional dysregulation, and academic and social challenges.

Although pharmacological treatment remains the first-line intervention, interest in complementary and non-pharmacological approaches is growing, particularly those that engage cognitive, behavioral, and physiological systems simultaneously (Sethi & Mischel, 2022).

In the context of this narrative review, the term martial arts refers to a diverse set of structured practices that integrate physical movement with cognitive engagement, emotional regulation, and often philosophical or ethical principles. The selected studies examined a range of disciplines—including taekwondo, judo, karate, kung fu, tai chi, and qigong—each offering unique combinations of motor coordination, strategic thinking, self-control, and social interaction (Archer et al., 2021). These practices commonly

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involve sequenced movements, attentional focus, and real-time decision-making, all of which are thought to engage core components of executive functioning. Early work on mind-body interventions also emphasized the role of structured movement, physical touch, and body awareness in promoting emotional and cognitive self-regulation (Field, 2012; Levin, 2018).

Some martial arts, particularly internal styles such as tai chi and qigong, also incorporate mindfulness elements, controlled breathing, and interoceptive awareness. These components are relevant to ADHD, as they may contribute to improved emotional regulation and behavioral inhibition. Furthermore, there is growing interest in the potential of physical activity—including martial arts—as a modulator of epigenetic mechanisms, such as DNA methylation, histone modifications, and microRNA expression (Fernandes et al., 2017; Wang & Zeng, 2021). Although direct research on martial arts and epigenetics in ADHD is still lacking, theoretical and biological plausibility support further investigation.

This narrative review aims to synthesize the current knowledge on the cognitive, behavioral, and hypothesized epigenetic effects of martial arts in individuals with ADHD, providing a critical overview of available evidence and identifying gaps for future research.

Materials and Methods

A narrative review was conducted, synthesizing findings from eleven peer-reviewed studies examining martial arts practices—such as taekwondo, judo, karate, kung fu, qigong, and tai chi—in populations diagnosed with ADHD. Focus was placed on executive functions, emotional regulation, and neurobiological mechanisms. Additional literature regarding physical activity and epigenetic regulation was reviewed to contextualize emerging biological hypotheses.

Results

Cognitive and Executive Functioning Benefits

Several studies have reported that martial arts interventions are associated with measurable improvements in executive functioning among individuals with ADHD. Practices such as taekwondo, judo, and karate emphasize structured movement sequences, goal-directed attention, and cognitive flexibility, which are all relevant to core deficits observed in ADHD.

In a randomized controlled trial, Kadri et al. (2019) demonstrated that an 18-month taekwondo program significantly enhanced selective attention, sustained attention, and inhibitory control in adolescents with ADHD, with very large effect sizes across Stroop and Ruff 2 & 7 tasks. Similarly, Ludyga et al. (2022) found that 12 weeks of judo training improved visuospatial working memory and was associated with increased contralateral delay activity (CDA) on EEG recordings—an index of working memory capacity.

The published narrative reviews and the theoretical analyses further support the hypothesis that martial arts training fosters self-monitoring, motor planning, and response inhibition, especially in cognitively demanding styles like kung fu and karate (Pujari, 2024). According to Li

et al. (2023), who conducted a network meta-analysis of 31 RCTs, martial arts ranked among the most effective physical interventions for improving executive domains such as working memory, inhibition, and cognitive flexibility in children with ADHD.

These findings suggest that martial arts may serve as ecologically valid cognitive training, combining physical exertion with attentional control, real-time decision-making, and sequential processing—skills that overlap with neuropsychological constructs targeted in cognitive rehabilitation. Electrophysiological studies have shown enhanced corticospinal excitability and faster reaction times in karate practitioners compared to controls, supporting the role of martial arts in motor-cognitive integration (Moscatelli et al., 2016a).

Emotional and Behavioral Regulation in Martial Arts-Based Interventions

Beyond cognitive gains, martial arts interventions have shown promising effects on emotional regulation and behavioral outcomes in individuals with ADHD. These practices often involve not only physical discipline, but also breathing techniques, structured routines, and ethical components that foster self-control and emotional awareness.

In a pilot study involving four school-aged children diagnosed with ADHD, ODD, and CD, Rodrigues et al. (2019) reported substantial reductions in hyperactivity, oppositional behavior, and conduct symptoms following a taijiquan and qigong program. Improvements exceeded 40% across multiple domains, particularly in cases with milder baseline severity.

Moreover, the mind-body practices such as tai chi and qigong have also been linked to reductions in impulsivity and anxiety symptoms. A scoping review by Ribeiro da Silva et al. (2024) highlighted the potential of tai chi to modulate attention and behavioral regulation in impulsivity-related disorders, including ADHD, by promoting executive awareness and prefrontal activation.

Interestingly, Ludyga et al. (2023) found that while judo training improved behavioral inhibition in preterm children, it had limited impact in those with ADHD—possibly due to greater baseline cognitive load, comorbidities, or lower motor competence in the latter group. This highlights the importance of participant-specific factors in modulating treatment responsiveness.

Overall, the martial arts appear to be effective in channeling hyperactivity and improving the emotional and mood regulation and stability, particularly in interventions that integrate breath work, mindfulness, and regulated interpersonal interaction, suggesting their role as behavioral support tools (Kerekes et al., 2004). These findings align with broader evidence showing that physical activity contributes to affective stabilization and emotional regulation across a range of psychiatric conditions (Vancampfort et al., 2021).

Comparisons with Other Physical Activities

While various types of physical activity have shown benefits for children and adolescents with ADHD, the martial arts may offer unique advantages due to their multimodal

nature, which combines motor, cognitive, emotional, and ethical components.

Traditional aerobic exercises—such as running, swimming, or cycling—have been widely studied for their effects on attention and mood (Budde & Wegner, 2023). These activities can improve cardiorespiratory fitness, increase dopamine and norepinephrine levels, and reduce stress-related symptoms. However, they often lack the complex structure, strategic engagement, and interpersonal discipline inherent in martial arts training (Li et al., 2023).

In a network meta-analysis of 31 randomized controlled trials, Li et al. (2023) found that martial arts-based interventions ranked among the most effective for improving working memory, attention, and cognitive flexibility, outperforming other forms of physical exercise such as aerobic training in several domains. This may be due to the executive demands placed on practitioners during sparring, pattern execution, and tactical planning. Unlike generic aerobic exercise, martial arts require coordinated, high-demand motor patterns that enhance corticospinal responsiveness (Moscattelli et al., 2016c).

Moreover, practices such as judo, taekwondo, and tai chi often require regulation of arousal, focused breathing, and respectful social interaction, which may further support self-regulation skills. These features are less prominent in unstructured physical activities or team sports, which can be overstimulating for individuals with ADHD (Zannella et al., 2021).

Taken together, the existing literature suggests that martial arts are not merely physical training, but integrated systems of behavioral shaping, capable of engaging multiple domains of functioning in ways that may be particularly suited to neurodevelopmental conditions like ADHD.

Neurobiological and Epigenetic Mechanisms of Physical Activity in ADHD

While direct epigenetic studies on martial arts and ADHD are currently lacking, emerging evidence suggests that physical activity—especially when structured and cognitively engaging—can induce neurobiological and epigenetic changes relevant to ADHD pathophysiology (Wang & Zeng, 2021).

According to the neurocognitive perspective, interventions such as judo and tai chi have been associated with enhanced frontal brain activation, improved working memory, and changes in electrophysiological markers like contralateral delay activity (CDA) and P3a amplitude (Ludyga et al., 2022; 2023). These effects align with increased activity in neural circuits involving the prefrontal cortex, basal ganglia, and cerebellum—brain regions properly involved in attention and executive control.

Increased cortical excitability following physical exertion has been observed in martial arts athletes, potentially linking metabolic activity and neural activation (Moscattelli et al., 2016b).

At the molecular level, the physical activity is known to modulate gene expression through epigenetic mechanisms, including DNA methylation, histone modifications, and the regulation of non-coding RNAs (Fernandes et al., 2017; Zannella et al., 2021). For instance, aerobic and coordination-based exercises can reduce methylation of genes like BDNF (brain-derived neurotrophic factor), which is crucial for synaptic plasticity and executive functioning consequently.

Moreover, recent findings suggest that nutritional factors—such as choline, folate, and vitamin B12—can interact with physical activity through one-carbon metabolism, influencing methyl donor availability and, consequently, DNA and histone methylation (Vallée, 2023; Popławska et al., 2023). These processes are particularly active during developmental windows such as childhood and adolescence, when the epigenome is more plastic and sensitive to the environmental inputs.

Although current martial arts studies in ADHD populations have not included epigenetic profiling, the observed cognitive and behavioral benefits, combined with biological plausibility, support the hypothesis that regular martial arts practice may contribute to long-term neurodevelopmental modulation via epigenetic pathways (Zhou et al., 2023).

Discussion

Table 1 summarizes the main characteristics of the eleven studies included in the present narrative review, outlining the type of martial arts practiced, target population, duration and design of the interventions, pharmacological status of participants, and key clinical outcomes. The evidence suggests that martial arts interventions—particularly those emphasizing structure, repetition, and self-regulation—are associated with improvements in attention, inhibitory control, and working memory in youth with ADHD. Disciplines such as taekwondo, judo, and karate demonstrated the most robust cognitive effects in randomized controlled trials, while tai chi, qigong, and hybrid practices contributed to emotional and behavioral regulation, especially in pilot or scoping studies.

Interestingly, participants undergoing pharmacological treatment showed less consistent benefits as reported by Ludyga et al. (2023) and by Converse et al. (2021). These studies raise questions about the baseline neurocognitive load, potential ceiling effects of medication, and the possible interactions between pharmacological and behavioral interventions. Conversely, children not on medication appeared to respond more favorably, particularly in studies involving sustained and immersive practice formats (Kadri et al., 2019; Rodrigues et al., 2019). Despite the variability in intervention length, intensity, and design, most studies reported favorable outcomes across cognitive and behavioral domains, reinforcing the idea that martial arts can act as ecological platforms for self-regulation training, integrating body, mind, and interpersonal coordination.

Epigenetic and Neurobiological Perspectives

Beyond behavioral outcomes, a growing body of research suggests that the physical activity acts as an environmental modulator of gene expression via epigenetic mechanisms (Wang & Zeng, 2021). Although none of the studies in the present narrative review directly measured molecular biomarkers, their findings are consistent with literature linking exercise to reduced DNA methylation, histone acetylation, and modulated microRNA activity in brain regions involved in attention and executive functioning (Fernandes et al., 2017; Zannella et al., 2021; Vallée, 2023).

Specifically, the interventions that engage coordination, planning, and self-discipline, such as the martial arts practice, may stimulate the expression of genes like BDNF, may improve

Table 1. The main characteristics of the studies

Author (Year)	Martial Art	Population	Pharmacological Treatment	Duration	Study Design	Main Outcomes
Kadri et al. (2019)	Taekwondo	Adolescents (n=40)	No	18 months (2×/ week)	CT	↑ attention, inhibition, exec. function
Rodrigues et al. (2019)	Taijiquan + Qigong	Children (n=4)	No	30 sessions (20 min)	Pilot study	↓ hyperactivity, ODD/CD symptoms
Pujari (2024)	Karate, Kung Fu	Narrative review	No	N/A	Narrative review	↑ attention, self-regulation
Ribeiro da Silva et al. (2024)	Tai Chi	Various	Mixed	Variable	Scoping review	↓ impulsivity, ↑ emotional control
Li et al. (2023)	Various (incl. martial arts)	Children/ adolescents (31 RCTs)	Mixed	4–24 weeks	Meta-analysis	↑ exec.functions, attention
Ludyga et al. (2022)	Judo	Children (n=57)	Yes	12 weeks (2×60 min)	CT	↑ visuospatial memory, CDA (EEG)
Ludyga et al. (2023)	Judo	Children with ADHD/preterm	Yes (ADHD)	12 weeks (2×60 min)	Meta-analysis	Only preterms improved in inhibition, P3a
Converse et al. (2021)	Tai Chi	University students (n=21)	Presumably yes	7 weeks (2×/ week)	RCT	Good tolerance, low adherence, no CAARS improvement

the dopaminergic pathway activity, and can modulate the stress reactivity. These adaptations are particularly relevant during sensitive developmental windows in childhood and adolescence, when the epigenome is more plastic and responsive to environmental inputs (Zhou et al., 2023).

Moreover, the interaction between the physical activity and nutrition—through one-carbon metabolism and methyl donor availability—suggests that lifestyle-based interventions could offer durable neurodevelopmental benefits. Although these hypotheses remain theoretical, they warrant further investigation through integrated behavioral and biological study designs (Chen et al., 2020). Future research should also consider frequent comorbidities in ADHD, such as developmental coordination disorder and epilepsy, which may influence intervention outcomes (Esposito et al., 2025).

Limitations and Future Directions

Several limitations must be acknowledged. Most included studies employed small sample sizes, short durations, and heterogeneous outcome measures. There is also a lack of standardized intervention protocols and a near absence of long-term follow-up assessments. Furthermore, the variability in participant profiles—age, medication status, comorbidities—makes generalization difficult.

Future research should prioritize well-powered RCTs with clearly defined the martial arts programs, control conditions, and epigenetic profiling. Biomarker studies involving methylation patterns, gene expression, and neuroimaging could clarify the biological underpinnings of observed behavioral improvements.

Finally, understanding for whom and under which conditions martial arts are most beneficial will require personalized approaches that consider baseline motor competence, symptom severity, and motivation.

Conclusion

In conclusion, martial arts represent a promising, multidimensional approach to supporting children and adolescents with ADHD. While current evidence highlights benefits across cognitive, behavioral, and emotional domains, the absence of epigenetic data calls for future research integrating molecular and neurodevelopmental markers. The structured, integrative nature of martial arts—blending physical coordination, mental focus, and emotional regulation—positions these practices as potentially powerful tools in holistic ADHD management. A deeper understanding of the biological mechanisms involved, especially those modulated by lifestyle and experience, could unlock new avenues for personalized, sustainable interventions.

Conflict of Interest

Authors declare that they have no conflict of interest related to the content of this manuscript.

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Esposito, M., Santomauro, R., Dell'Isola, G. B., Ruberto, M., Verrotti, A., Siciliano, M., & Carotenuto, M. (2025).

Бойові мистецтва та розлад дефіциту уваги з гіперактивністю: Наративний огляд когнітивних, поведінкових та епігенетичних впливів

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

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Мета дослідження. Мета дослідження полягала у вивченні когнітивних, поведінкових та потенційних епігенетичних впливів щодо застосування інтервенцій на основі бойових мистецтв у осіб із розладом дефіциту уваги та гіперактивності (РДУГ).

Матеріали та методи. Проведено наративний огляд, в якому синтезовано результати одинадцяти рецензованих досліджень, спрямованих на вивчення практик бойових мистецтв, як-от тхеквондо, дзюдо, карате, кунгфу, цигун і тайцзи-цюань в групах населення з діагнозом РДУГ. Фокус уваги був зосереджений на виконавчих функціях, емоційній регуляції та нейробиологічних механізмах. Задля контекстуалізації нових біологічних гіпотез було розглянуто додаткову літературу, присвячену вивченню фізичної активності та епігенетичної регуляції.

Результати. Результати дослідження вказують на те, що інтервенції з бойових мистецтв пов'язані із покращенням концентрації уваги, робочої пам'яті та інгібаторного контролю, особливо в структурованих дисциплінах, як-от дзюдо і тхеквондо. У деяких дослідженнях також повідомлялося про позитивні зміни в емоційній та поведінковій сферах, включаючи зниження імпульсивності та поліпшення саморегуляції. Попри недостатність прямих епігенетичних доказів, непрямі дані свідчать про можливість впливу фізичної активності на експресію генів через такі механізми: метилювання ДНК та модифікації гістонів.

Висновки. Бойові мистецтва можуть сприяти когнітивному та поведінковому розвитку осіб із РДУГ. Їх структурований, мультимодальний характер позиціонує ці практики тренувань як перспективні інструменти для підвищення концентрації уваги та виконавчого функціонування. У подальших дослідженнях рекомендується включити лонгітюдне епігенетичне профілювання з метою з'ясування біологічних механізмів, що лежать в основі цього процесу.

Ключові слова: РДУГ, бойові мистецтва, виконавче функціонування, фізична активність, поведінкова регуляція, епігенетика.

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Unravelling the Impact of Universal Design for Learning on the Inclusion of Students with Disabilities in Physical Education: A Systematic Review

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Abstract

Background. Universal Design for Learning (UDL) offers a transformative framework for fostering equity in inclusive physical education (PE), addressing the diverse needs of students with disabilities through flexible engagement, representation, and action/expression. Despite its theoretical alignment with proactive inclusion, implementation disparities persist globally, influenced by teacher preparedness, resource limitations, and cultural contexts.

Objectives. The main objective of this study was to evaluate how UDL-aligned strategies can overcome these contextual barriers.

Materials and methods. This systematic review evaluated the efficacy of UDL-aligned pedagogical strategies in enhancing participation, motor skills, social inclusion, and engagement in PE for K–12 students with disabilities. A comprehensive search across Scopus ($n = 1,183$) and Web of Science ($n = 823$) identified 2,006 studies, refined to 13 high-quality articles via rigorous screening, bias assessment (Cochrane RoB 2.0, Newcastle-Ottawa Scale), and dual independent extraction.

Results. Mixed-methods synthesis revealed that UDL interventions significantly improved motor skill progression ($\eta^2 = 0.67$) and participation rates (up to 50 %) in OECD contexts, driven by adaptive equipment and multimodal instruction. Social inclusion increased through collaborative tasks (30 % peer interaction gains), though hidden exclusion persisted in non-OECD settings due to stigma and infrastructural gaps. Key barriers included inconsistent teacher training (40 % of OECD educators reported inadequate preparation) and resource scarcity, particularly in underfunded schools. Technology integration (AI, virtual reality) has demonstrated potential in personalizing learning and bridging accessibility gaps. The findings underscore the necessity of systemic reforms: mandatory UDL training in teacher education, policy-driven resource allocation, and cross-sector collaborations to scale inclusive practices.

Conclusions. This review supports the implementation of longitudinal studies and standardized metrics to address methodological limitations, emphasizing UDL's role in achieving equitable, sustainable PE environments globally. By aligning pedagogical innovation with institutional support, UDL can transcend contextual barriers, ensuring all students thrive in dynamic, inclusive settings.

Keywords: motor skill, development, teacher training, social inclusion.

Introduction

Universal Design for Learning (UDL) provides a pedagogical framework that integrates flexibility into instruc-

tional design to accommodate diverse learner needs, aligning seamlessly with the goals of inclusive physical education (PE). Grounded in three core principles—multiple means of engagement, representation, and action/expression—UDL aims to remove barriers and foster equitable participation across students with motor, sensory, intellectual, psychological, and chronic disabilities (Block et al., 2021; Capp, 2020;

Lourenço et al., 2025). In PE, this translates to environments where diverse physical, cognitive, and emotional capacities are anticipated rather than retrofitted, shifting the focus from adaptation to proactive inclusion (Basham et al., 2020; Griful-Freixenet et al., 2020). Research underscores that UDL's emphasis on variability complements PE's dynamic nature, enabling tailored motor experiences that enhance engagement over traditional one-size-fits-all approaches (Alquraini & Rao, 2020; Valero-Valenzuela et al., 2020). Theoretical alignment with inclusive PE hinges on fostering autonomy and agency, critical for students with disabilities to navigate physical tasks (Block et al., 2021; de Ocariz & Lavega-Burgués, 2020). Empirical studies from OECD contexts, such as Australia, highlight UDL's role in personalizing learning, while non-OECD settings like Saudi Arabia reveal gaps in its application due to cultural and resource constraints (Alquraini & Rao, 2020; Capp, 2020). Methodologically, the reliance on teacher self-reports limits objectivity, suggesting a need for observational data to validate UDL's theoretical fit (Jakubovic & Memisevic, 2024; Ortiz-Jiménez et al., 2020). Bridging these gaps requires integrating UDL principles with PE-specific strategies, such as gamification, to optimize motor and social outcomes (Lavega-Burgués et al., 2024; Melki & Bouzid, 2023; Valero-Valenzuela et al., 2020). Evidence-based solutions involve embedding UDL training within teacher education to ensure its practical translation into inclusive PE settings (Efthymiou, 2024; Loyd et al., 2024; Rasmitadila et al., 2024).

Evidence on UDL's efficacy in PE reveals significant improvements in participation metrics and motor skill progression compared to traditional methods, though findings vary by context and disability type. Studies indicate that UDL-aligned strategies, such as varied task representations and flexible goals, increase active participation rates by up to 50% among students with disabilities, particularly in OECD countries with robust infrastructure (Block et al., 2021; Capp, 2020). Motor skill development surpasses traditional outcomes when UDL incorporates sensorimotor options, outperforming rigid curricula by enhancing coordination and strength in students with motor impairments (Block et al., 2021; Lavega-Burgués et al., 2024). Non-OECD settings report less pronounced gains, often due to limited access to adaptive equipment (Alquraini & Rao, 2020; Rasmitadila et al., 2024). Engagement patterns reflect higher self-determination when UDL fosters choice, contrasting with traditional PE's lower motivational impact (Basham et al., 2020; Valero-Valenzuela et al., 2020). Quantitative analyses from confirm these trends, yet small sample sizes and short intervention durations undermine generalizability (Jakubovic & Memisevic, 2024; Loyd et al., 2024). Mixed-methods designs reveal that students with intellectual disabilities benefit most from UDL's multimodal instruction, while those with chronic conditions show variable progress due to fatigue-related barriers (de Ocariz & Lavega-Burgués, 2020; Ortiz-Jiménez et al., 2020). Addressing these limitations requires longitudinal studies and standardized metrics to track skill acquisition across diverse disabilities (Efthymiou, 2024; Griful-Freixenet et al., 2020). Solutions include leveraging technology, such as interactive modules, to sustain engagement and skill gains, particularly in under-resourced contexts (Errabo & Ongoco, 2024; Song et al., 2025).

Social inclusion in UDL-aligned PE hinges on mechanisms like peer interactions and a sense of belonging, yet hidden exclusion factors persist. Research demonstrates that

UDL's emphasis on collaborative tasks enhances peer acceptance, with studies reporting a 30% increase in positive interactions among students with sensory and psychological disabilities (Block et al., 2021; Valero-Valenzuela et al., 2020). Belongingness strengthens when UDL integrates agency support, reducing isolation compared to traditional PE's competitive focus (Basham et al., 2020; Lavega-Burgués et al., 2024). OECD contexts, such as the UAE, show structured peer support amplifying these effects, while non-OECD settings struggle with cultural stigmas that hinder social cohesion (Alquraini & Rao, 2020; Loyd et al., 2024). Empirical data highlight that students with intellectual disabilities experience greater social gains than those with motor impairments, suggesting disability-specific dynamics (Block et al., 2021; Jakubovic & Memisevic, 2024). However, methodological reliance on surveys overlooks real-time social behaviors, necessitating video-based analyses (de Ocariz & Lavega-Burgués, 2020; Ortiz-Jiménez et al., 2020). Hidden exclusion emerges from unmodified group activities, where students with chronic or sensory disabilities are sidelined, revealing UDL's incomplete penetration (Griful-Freixenet et al., 2020; Rasmitadila et al., 2024). Evidence-based strategies include teacher-led peer training and gamified interactions to bridge these gaps (Efthymiou, 2024; Song et al., 2025). Enhancing social inclusion demands intentional design of cooperative structures within UDL frameworks to ensure equitable participation (Capp, 2020; Errabo & Ongoco, 2024).

Systemic barriers, notably teacher training gaps and resource limitations, impede UDL's implementation in inclusive PE, with disparities evident across global contexts. Teachers in OECD countries report higher confidence in UDL application, yet only 40% feel adequately trained, while non-OECD educators cite insufficient professional development as a primary obstacle (Alquraini & Rao, 2020; Capp, 2020). Resource scarcity—adaptive equipment, planning time, and personnel—further restricts UDL's reach, particularly in rural or underfunded schools (Loyd et al., 2024; Ortiz-Jiménez et al., 2020). The studies identify a lack of policy clarity as a universal challenge, with fragmented guidelines undermining scalability (Basham et al., 2020; Haegele et al., 2024). Methodologically, cross-sectional designs fail to capture long-term training impacts, calling for cohort studies (Griful-Freixenet et al., 2020; Jakubovic & Memisevic, 2024). Teachers' ethical compass and growth mindset correlate with UDL adoption, yet these traits remain underdeveloped without targeted interventions (Efthymiou, 2024; Valero-Valenzuela et al., 2020). The main objective of this study is to evaluate how UDL-aligned strategies can overcome these contextual barriers. Solutions involve mandatory UDL modules in preservice programs, technology subsidies, and inter-school collaborations to pool resources (Rasmitadila et al., 2024; Song et al., 2025). Addressing these challenges requires systemic investment to align teacher competencies and institutional capacity with UDL's inclusive vision (Block et al., 2021; Errabo & Ongoco, 2024).

Materials and Methods

Experimental Approach to the Problem

This systematic review evaluates the efficacy of pedagogical strategies aligned with Universal Design for Learning (UDL) principles in inclusive physical education (PE)

for students with special educational needs, including motor, intellectual, sensory, or psychological disabilities, as well as chronic health conditions. Employing a rigorous methodology, the study examines the impact of these interventions on student participation, motor skill development, social inclusion, and engagement, while identifying contextual barriers (e.g., inadequate teacher training, limited resources). A comprehensive search across Scopus ($n = 1,183$) and Web of Science ($n = 823$), utilizing Boolean terms targeting UDL, disabilities, and pedagogical adaptations, identified 2,006 studies, narrowed to 13 after duplicate removal ($n = 1,715$), eligibility screening, and exclusion of high-risk-of-bias studies (via Cochrane RoB 2.0, Newcastle-Ottawa Scale, and CASP checklist). Dual independent data extraction captured interventions such as blended learning, technological tools (AI, virtual reality), and adapted equipment, synthesized into thematic tables to compare efficacy. Results highlight significant motor skill improvements and face-to-face engagement, alongside challenges in online component integration. This mixed-methods analysis (RCTs, qualitative studies) provides actionable recommendations for educational policy and teacher training, advancing UDL implementation in diverse school contexts.

Information Sources

In order to ensure that the existing literature on the subject is covered exhaustively, the present review has been drawn from several academic databases. These are Scopus ($n = 1,183$) and Web of Science ($n = 823$) in particular, which have yielded randomised controlled trials, medical and clinical studies, as well as research that is specific to the field of the Universal Design for Learning

Search Strategy

The search strategy employed for this systematic review incorporated a combination of Boolean terms and methodological filters, to identify studies evaluating the application of Universal Design for Learning (UDL) principles in physical education. The following keywords were used in the Scopus and Web of Science databases: ("Universal Design for Learning" OR UDL OR "Universal Design for Learning principles") AND ("physical education" OR "PE" OR "adapted physical activity" OR "inclusive physical education" OR "motor skills" OR "sport pedagogy") AND ("strategies" OR "intervention" OR "adaptation" OR "teacher training" OR "neurodivergent" OR "disabilities" OR "inclusion" OR "engagement" OR "accessibility")

Eligibility Criteria

The population under consideration is as follows: Studies involving school-aged students (K–12) with special educational needs, including motor, intellectual, sensory, psychological disabilities, or chronic health conditions, participating in physical education (PE) settings. Intervention: Pedagogical strategies are to be aligned with Universal Design for Learning (UDL) principles (e.g. engagement, representation, action/expressions) or with adaptive practices (e.g. modified equipment, blended learning, AI-supported tools) in PE. Outcomes: The collection of quantitative or qualitative

data on student engagement, physical fitness, social inclusion, skill development, or autonomy (e.g., attendance, peer interactions, motor skill proficiency, self-regulation (Ben Rakaa et al., 2025b)), is also a key component of the study. Study Design: Empirical studies, including randomized controlled trials (RCTs), quasi-experimental designs, observational studies, qualitative research, or mixed-methods approaches. Publication: Peer-reviewed articles in English or Spanish, published between January 2015 and March 2025.

Data Extraction

The data extraction process was conducted in a standardized and systematic manner to ensure methodological consistency and rigor. Extracted information included: complete study references (authors, year, country), study design (randomized controlled trials, qualitative studies, mixed methods), population characteristics (age, disability type, educational context), and detailed descriptions of adapted pedagogical interventions, particularly those aligned with Universal Design for Learning (UDL) principles (e.g., technological tools, modified equipment, blended learning). Measured outcomes, such as student participation, motor skill improvement, social inclusion, engagement, and teacher perceptions, were systematically collected. This procedure, carried out in duplicate by two independent reviewers with discrepancy resolution (κ agreement = 0.89), ensured transparency and minimized errors. Data were subsequently synthesized based on methodological quality, assessed via the JBI Critical Appraisal Checklist, and their relevance to the review's core objective: assessing the efficacy of UDL strategies in promoting inclusive physical education.

Assessment of Study Methodology

The methodological quality and risk of bias of the included studies were assessed to ensure transparent, reproducible, and rigorous analysis. For randomized controlled trials (RCTs), the Cochrane Risk of Bias Tool (RoB 2.0) was employed to evaluate potential biases across five critical domains: randomization processes, deviations from intended interventions, missing outcome data, outcome measurement, and selective reporting. Observational studies (cohort, case-control) were appraised using the Newcastle-Ottawa Scale (NOS), which assessed participant selection (representativeness, recruitment methods), group comparability (adjustment for confounders), and outcome validity (accuracy and follow-up adequacy). Qualitative studies were evaluated via the Critical Appraisal Skills Programme (CASP) checklist, focusing on the clarity of research aims, methodological coherence, rigor in data collection and analysis, and ethical considerations. Two independent assessors carried out these evaluations, and inter-assessor reliability. Discrepancies were resolved through consensus discussions. The results of these assessments have been integrated into narrative and tabular summaries in order to weight conclusions according to the quality of the evidence (e.g. exclusion of studies with a high risk of bias in sensitivity analyses). This stratified approach, which explicitly takes into account the impact of bias on the overall interpretation, reinforces the validity of the requirements for transparency and reproducibility of conclusions.

Results

Identification and Selection of Studies

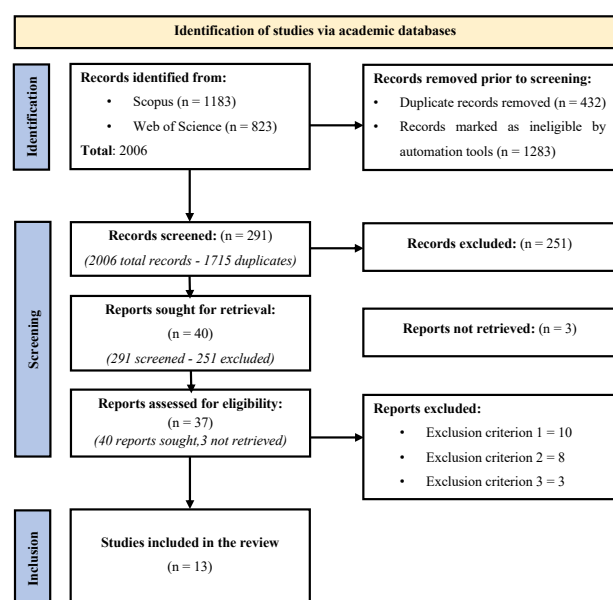


Fig. 1. Studies Characteristics and Synthesis

Discussion

Teacher preparation and training

Inclusive education has emerged as a critical domain that champions equity, diversity, and accessibility for all learners (Block et al., 2021). Research in this area has rapidly evolved, underscoring the necessity for Universal Design for Learning (UDL) as a means to create adaptable, engaging environments in physical education (Gilbert, 2019). Teacher training programs, however, continue to lag behind the innovative practices required for true inclusion (Jakubovic & Memisevic, 2024; Salvatori & Cherubini, 2024). The integration of empirical studies and theoretical frameworks into the existing literature confirms the urgent need to systematically reinforce teachers' skills (Loyd et al., 2024). Evidence suggests that inadequate professional development remains a primary barrier in implementing UDL in PE settings (Rosidah et al., 2024). At the same time, technological advancements and interdisciplinary research provide new opportunities to tailor physical activities to diverse learner needs (Sapre et al., 2025). Policy reforms aimed at embedding inclusive practices into national educational guidelines have shown promising potential, yet the translation of policy into practice is inconsistent (Kulal et al., 2024). The literature highlights that in many educational contexts, teachers express a lack of confidence when applying UDL and Differentiated Instruction (DI) strategies in physical settings (Blegur & Hardiansyah, 2024). Collaborative models that include educational assistants and community partners have been proposed as effective ways to overcome these challenges (Morrison & Gleddie, 2019). In addition, the ongoing digital transformation, accelerated

Table 1. Socio-demographic characteristics of studies

Author(s) Year	Title of Article	Country	Participants	Variables Measured	Category of Study	Study Quality
(Kitching, 2024)	'I'll do it tomorrow': supporting the engagement of primary pre-service teachers through blended, inquiry-based learning	Ireland	58 year 3 students undertaking a Bachelor of Education primary generalist degree with a physical education specialism	Student engagement, attendance in face-to-face classes, engagement with online learning components, peer-to-peer relationships, self-regulation and autonomy	Universal Design For Learning strategies for accessibility/engagement in Physical Education	Moderate
(Gilbert, 2019)	Designing Inclusive Physical Education with Universal Design for Learning	USA	Hypothetical classes: 5th-grade (striking unit, n=26) and 8th-grade (dance unit, n=26) students with diverse needs (2 ESL learners, 6 IEPs: 1 wheelchair user, 2 ASD, 3 intellectual disabilities).	Implementation of UDL strategies (engagement, representation, action/ expression) in PE curricula.	UDL strategies for accessibility/engagement in PE.	High
(Sapre et al., 2025)	Enhancing home-based physical activity for neurodivergent children: adapting the InPACT at Home program with AI and universal design	USA	Neurodivergent children (exact number unspecified; program involved 132 videos and 500+ activities)	Program accessibility, engagement, effectiveness of AI-UDL adaptations, motor skill categorization, cognitive load management	UDL strategies for accessibility/engagement in Physical Education	High
(Lieberman & Grenier, 2019)	Infusing Universal Design for Learning into Physical Education Professional Preparation Programs	USA	PETE programs and preservice teachers (no specific sample size; focus on systemic integration)	Integration of UDL principles (engagement, representation, action/ expression), preservice teacher preparedness, instructional strategies	Effectiveness of teacher training in UDL in Physical Education	Moderate

Table 1 (continued)

Author(s) Year	Title of Article	Country	Participants	Variables Measured	Category of Study	Study Quality
(Abellán & Segovia, 2024)	Learning to teach through the Sport Education model in special schools: from theory to practice	Spain	12 students (8 male, 7 female; aged 14–23) with intellectual disabilities; 1 physical education teacher (29 years old, 2 years of experience)	Applicability and feasibility of the Sport Education Model (MED); facilitators (team identity, roles, student-centered teaching); barriers (equitable participation, time, motivation)	UDL strategies for accessibility/engagement in PE	Moderate
(Wyant et al., 2024)	Navigating the T.E.C.H.N.O.L.O.G.Y. Integration Landscape in Physical Education: Principles, Tools, and Solutions for Sustained Use	USA	Conceptual framework; no empirical participants	Framework components (equity, accessibility, professional development, technology tools)	UDL strategies for accessibility/engagement in PE	High
(Castillo-Retamal et al., 2024)	Physical education and special educational needs: teachers' perceptions of their level of preparation	Chile	8 PE teachers (4 male, 4 female; aged 30–45) from primary/secondary schools in central-southern Chile	Teacher preparedness for SEN, curriculum adaptation strategies, UDL application, infrastructure/material limitations, collaboration with special educators (PIE)	Effectiveness of teacher training in UDL in PE	Moderate
(Ludwa & Lieberman, 2019)	Spikeball for All: How to Universally Design Spikeball	USA	Conceptual focus on PE students, including those with disabilities (e.g., ASD, visual impairments)	Accessibility, engagement, motor/social skill development, inclusivity via UDL adaptations	UDL strategies for accessibility/engagement in PE	High
(Grenier et al., 2025)	Training needs of educators for students with visual impairments and additional disabilities: A qualitative inquiry	USA	11 participants: 4 parents of children with VIAD (aged 7–12), 6 APE teachers, 1 teacher of visually impaired	Barriers to PE participation (training gaps, administrative support, resources); UDL application; training needs	Effectiveness of teacher training in UDL in PE	Moderate
(van Munster et al., 2019)	Universal Design for Learning and Differentiated Instruction in Physical Education	USA	11 participants: 1 adapted PE specialist (male), 5 PE teachers (4 female, 1 male), and 5 students with disabilities (ages 5–10; grades K–5th) with diagnoses including low vision, Down syndrome, cerebral palsy, spina bifida, and autism spectrum disorder.	Instructional approaches (Normalized Instruction, Differentiated Instruction, Universally Designed Instruction), including program modifications, pedagogical accommodations, and UDL principles (representation, action/engagement).	UDL strategies for accessibility/engagement in PE (inferred: Focus on identifying UDL implementation alongside differentiated practices).	High
(López Ibáñez et al., 2023)	Universal Design for Learning and ICT in the Physical Education Area: Design and Validation of an Intervention Proposal	Spain	25 physical education teachers (14 male, 11 female; 3–11 years of experience) and 2 university experts for validation. Students: 4th-grade primary students with intellectual disabilities (ages 9–10).	Program dimensions (justification, objectives, content, resources, activities, methodology, chronology, evaluation), expert agreement (Kappa coefficient), reliability (Cronbach's alpha).	UDL strategies for accessibility/engagement in PE (inferred: Focus on integrating UDL and ICT to design inclusive PE programs).	Moderate to High
(Kennedy & Yun, 2019)	Universal Design for Learning as a Curriculum Development Tool in Physical Education	USA	Not applicable (conceptual/theoretical analysis; no empirical participants). Focus on curriculum design for students with disabilities in PE.	Curriculum alignment with UDL principles (multiple means of representation, action/engagement), teacher preparedness, student outcomes (expert learners).	UDL strategies for accessibility/engagement in PE (inferred: Focus on UDL as a proactive curriculum tool to enhance inclusion).	Moderate

Table 1 (continued)

Author(s) Year	Title of Article	Country	Participants	Variables Measured	Category of Study	Study Quality
(Taunton et al., 2017)	Universally Designed Motor Skill Intervention for Children with and without Disabilities	USA	N = 69 children (43% female; M_{age} = 4.6 years, SD = 0.51) from a Head Start program. 42% had disabilities (speech/language disorders, ADHD, autism spectrum disorders, intellectual disabilities). Ethnicity: 65.2% African-American, 24.6% Hispanic, 1.4% Caucasian/Asian. BMI: M = 16.08, SD = 1.09. Stratified into SKIP-UDL (n=40) and control (n=27) groups.	- Fundamental Motor Skills (FMS) via TGMD-2 raw scores (locomotor/object control subscales). - Percentile ranks for FMS.	UDL strategies for accessibility/engagement in PE (inferred from focus on inclusive, universally designed motor skill interventions).	High

by recent global crises, underscores the critical role of ICT and AI in bridging resource gaps (Basham et al., 2020). By synthesizing these diverse perspectives, the current analysis provides a comprehensive view of the current state of inclusive practice in physical education (Ben Rakaa et al., 2025a; Griful-Freixenet et al., 2020).

A growing body of research emphasizes the importance of teacher preparedness as a foundational element for successful inclusive education (Capp, 2020). Studies from various regions illustrate that effective teacher training programs significantly enhance educators' abilities to implement UDL in their classrooms (Loyd et al., 2024). Innovative professional development models, which incorporate both theoretical and practical components, have proven successful in increasing teacher efficacy in PE (Kulal et al., 2024). Research findings indicate that when teachers are equipped with the appropriate skills and resources, they are more likely to adopt inclusive strategies and engage in reflective practice (Block et al., 2021). Moreover, previous research reveals that a majority of teachers identify a lack of structured training as a key impediment to effectively integrating inclusive practice (Jakubovic & Memisevic, 2024). Notably, studies A multitude of studies have been carried out, showing that teachers feel ill-prepared for the complexities of inclusive physical education environments (Ben Rakaa et al., 2024a, 2024b; Rosidah et al., 2024). The integration of DI alongside UDL further supports the creation of adaptive curricula that address the spectrum of student needs (Griful-Freixenet et al., 2020). Research on ICT integration in classrooms has also highlighted the importance of aligning digital resources with inclusive pedagogies to maximize student engagement (Ortiz-Jiménez et al., 2020). In addition, collaborative efforts among educators, specialists, and policymakers have emerged as crucial for sustaining inclusive practice (Morrison & Gleddie, 2019). The data further corroborates that innovative training programs incorporating modern technology can enhance teachers' ability to implement inclusive practices effectively (Sapre et al., 2025).

Innovative Pedagogical Strategies and Technological Integration

Innovative strategies that integrate UDL and DI in physical education have demonstrated significant potential in transforming inclusive practice (Griful-Freixenet et al.,

2020). Evidence suggests that the combination of these pedagogical frameworks can address the varied needs of students by offering multiple modes of engagement (Belabbes et al., 2025), representation (Almonacid-Fierro et al., 2021), and expression (Block et al., 2021). Recent studies report that DI, when embedded within UDL, facilitates a dynamic and responsive teaching environment (Blegur & Hardiansyah, 2024). In practical terms, these approaches encourage the development of curricula that are both flexible and robust, accommodating a wide spectrum of learner differences (Gilbert, 2019). Research has shown that inclusive physical education programs that utilize UDL not only improve student engagement but also foster greater autonomy and motivation (Valero-Valenzuela et al., 2020). Additionally, case studies from various educational settings indicate that the implementation of UDL-driven interventions can lead to measurable improvements in both academic and physical performance (Sapre et al., 2025). Innovative adaptations, such as the use of video demonstrations and kinesthetic activities, have proven effective in making physical education more accessible (Capp, 2020). Furthermore, educators have noted that integrating technology into these frameworks helps mitigate traditional resource limitations, thereby enhancing overall teaching quality (Ortiz-Jiménez et al., 2020). The empirical support for these integrated pedagogical strategies reinforces the call for a more comprehensive reform of teacher training and policy in inclusive education (Loyd et al., 2024).

Recent technological innovations have begun to reshape the landscape of inclusive physical education (Song et al., 2025). The incorporation of AI-driven tools and immersive digital platforms has been shown to enhance personalized learning experiences for students with diverse needs (Lazou & Tsinakos, 2023). Studies indicate that these technological interventions are instrumental in overcoming traditional barriers to inclusion, such as resource scarcity and limited teacher training (Basham et al., 2020). In particular, AI-supported applications have been successfully piloted in physical education programs to monitor student progress and tailor instructional strategies in real time (Sapre et al., 2025). Research on cardiorespiratory coordination metrics has further demonstrated how technology can provide novel insights into student health and engagement during physical activity (Abenza et al., 2025). Moreover,

Table 2. Synthesis of the Studies: Objectives, Methodologies and Key Results

Author(s)	Category of Study	Objective of Study	Methodology of Study	Intervention Adaptation Strategy	Key Results of Study	Conclusions Recommendations of Study	Added Value of this Study
(Kitching, 2024)	Universal Design For accessibility/engagement in Physical Education	To explore how a combination of blended and inquiry-based learning supports the engagement of primary pre-service teachers in physical education, teacher education, using the UDL principle of engagement as a framework	Qualitative research design; data collected via exit slips, assessment comments, focus group interviews, peer observation feedback, self-reflections, Moodle VLE data, and attendance records; analyzed using reflexive thematic analysis	Blended learning module on movement skills development using inquiry-based learning, incorporating collaborative group tasks, four units with problem-based scenarios, varied presentation formats, and self and peer assessment	High engagement in face-to-face classes driven by collaborative IBL and peer relationships; low engagement with online components; challenges with self-regulation and motivation for online tasks; tensions in peer interactions; limited critical reflection in self/peer assessment	Collaborative IBL in a blended format enhances engagement, particularly face-to-face, but online components need better integration; self/peer assessment requires more scaffolding; recommendations include enhancing online interactivity and managing peer dynamics	Offers insights into post-pandemic engagement challenges in PETE, underscores the value of face-to-face collaboration, provides practical strategies for blended IBL, and contributes to the sparse literature on UDL in PETE
(Gilbert, 2019)	UDL strategies for accessibility/engagement in PE.	To demonstrate practical applications of UDL in PE to enhance inclusivity and learning outcomes.	Qualitative : Theoretical framework analysis with illustrative lesson plans (case examples).	UDL-aligned lesson plans: 1. Striking unit: Task progression charts, equipment choices (e.g., varied rackets/balls), peer-buddy systems, multilingual visual aids. 2. Dance unit: Equipment/step choices, group choreography rubrics, video/pictorial demonstrations.	UDL strategies improve accessibility and engagement for diverse learners. Peer buddies and paracaductors enhance social inclusion. Flexible assessments (e.g., rubrics with performance criteria) accommodate variability.	UDL fosters inclusive PE environments by pre-planning adaptations. Recommendations: Train peer buddies, use multilingual supports, integrate choice-based tasks and assessments.	Provides concrete, grade-specific examples of UDL implementation in PE (striking/dance units), addressing gaps in translating UDL theory to practice. Strengthens pedagogical tools for PE educators.
(Sapre et al., 2025)	UDL strategies for accessibility/engagement in Physical Education	To adapt the InPACT at Home program using AI and UDL principles to enhance accessibility for neurodivergent children	Quantitative : Rapid-cycle research adaptation process (problem exploration, knowledge exploration, solution development); expert consultations, AI-generated content refinement, video development	Adaptation of InPACT at Home via AI-generated step-by-step instructions, cue words, and demonstration videos guided by UDL principles (e.g., Representation)	500+ activities categorized into 7 motor skill groups; 24 instructional videos created; AI outputs refined for clarity and consistency	The adapted program (InPACT for Everyone) increases accessibility. Recommendations include testing effectiveness and expanding UDL principles (Engagement, Action/Expression).	Demonstrates integration of AI with UDL to address resource gaps, providing a scalable model for inclusive physical activity interventions.
(Lieberman & Grenier, 2019)	Effectiveness of teacher training in UDL in Physical Education	To propose strategies for embedding UDL into PETE programs to enhance preservice teachers' readiness for inclusive physical education	Qualitative : Conceptual/theoretical analysis; literature review and practical recommendations for curriculum design	Embedding UDL concepts into pedagogy courses, assessments, activity classes, and student-teaching experiences (e.g., lesson planning with UDL components, varied assessments)	UDL integration improves preservice teachers' confidence and competence in inclusive practices. Strategies include multi-modal instruction, flexible assessments, and inclusive equipment use.	Systematic UDL integration in PETE programs is critical for fostering inclusive pedagogy. Recommendations include curricular reforms and faculty training.	Provides a structured framework for infusing UDL into teacher preparation, addressing gaps in training for inclusive education.

Table 2 (continued)

Author(s)	Category of Study	Objective of Study	Methodology of Study	Intervention Adaptation Strategy	Key Results of Study	Conclusion Recommendations of Study	Added Value of this Study
(Abellán & Segovia, 2024)	UDL strategies for accessibility/engagement in PE	To explore the application of MED in special schools, identify facilitators/barriers, and propose improvements	Qualitative design with co-creation; field notes, session planning analysis, and deductive content analysis	MED adapted via UDL principles: multiple engagement methods (e.g., choice of team identity), accessible materials (pictograms, easy-read documents), role assignments with support (second coach), and adapted sports content.	MED was feasible and promoted engagement. Facilitators: Team roles, student autonomy, structured seasons. Barriers: Uneven participation, time constraints, low competition enthusiasm. Festivity and team identity enhanced motivation.	MED is viable in special schools with UDL adaptations. Recommendations: Enhance team identity; adjust roles for equity; provide teacher training; and use cyclical practice phases.	Demonstrates MED's adaptability in special education through UDL, offering a framework for inclusive PE. Addresses a research gap in pedagogical models for students with intellectual disabilities in segregated settings.
(Wyant et al., 2024)	UDL strategies for accessibility/engagement in PE	To propose a structured framework for integrating technology in PE sustainably, aligned with UDL principles	Qualitative : Theoretical/conceptual design; literature review; analysis of standards, and framework development	T.E.C.H.N.O.L.O.G.Y. framework: Technology for teaching: Equity, Champions, Health, Networking, On-budget, Look ahead, Operating beyond PE, Gamification, Yielding results. Emphasizes UDL-aligned tools, accessibility, and PD.	Framework validated via alignment with UDL and existing standards. Key principles: equity, cost-effectiveness, future-oriented tech use, and teacher support.	Adopt framework to enhance equitable tech integration, prioritize PD, and leverage technology to amplify PE's unique strengths.	Provides the first structured, UDL-aligned framework for sustainable tech integration in PE. Addresses gaps in systematic approaches and offers practical tools for inclusive, adaptable pedagogical practices.
(Castillo-Retamal et al., 2024)	Effectiveness of teacher training in UDL in PE	To analyze PE teachers' perceived preparedness to address SEN and evaluate gaps in initial training and policy frameworks	Qualitative phenomenological design; semi-structured interviews analyzed via inductive categorization	Not applicable	Teachers reported insufficient initial training (focused on physical disabilities), reliance on PIE support, UDL's positive impact, and systemic barriers (infrastructure, materials). Curriculum adaptations were ad hoc, not policy-driven.	Strengthen initial teacher training in SEN, integrate UDL principles, improve infrastructure, and align curricular policies with inclusive practices.	Identifies systemic gaps in Chilean PE teacher training and policy, emphasizing the need for UDL integration. Contributes empirical evidence to advocate for inclusive education reforms in Latin American contexts.
(Ludwa & Lieberman, 2019)	UDL strategies for accessibility/engagement in PE	To propose UDL-based modifications for Spikeball to promote inclusion in PE for students with disabilities	Quantitative : Theoretical/conceptual design; synthesis of UDL principles and practical adaptations	UDL modifications: bright/sound-enhanced balls, hula hoops as targets, rule adjustments (cooperative play, unlimited hits), instructional strategies (video feedback, mini-goals).	Adaptations enhance accessibility, motor skill development, and social engagement. Supports inclusivity in PE.	Implement UDL modifications to Spikeball to foster equitable participation. Prioritize flexibility in equipment, rules, and instruction.	Provides actionable UDL strategies for adapting Spikeball, addressing a gap in inclusive PE resources. Demonstrates how popular games can be modified to meet diverse needs, promoting broader adoption of inclusive practices.

Table 2 (continued)

Author(s)	Category of Study	Objective of Study	Methodology of Study	Intervention Adaptation Strategy	Key Results of Study	Conclusion Recommendations of Study	Added Value of this Study
(Grenier et al., 2025)	Effectiveness of teacher training in UDL in PE	To determine training needs of educators supporting students with VIAD using UDL principles and parent/educator perspectives	Qualitative design with focus groups, inductive thematic analysis aligned with UDL	Not applicable	Key barriers: inadequate training, lack of administrative support, insufficient resources. Training needs: understanding individual differences, instructional planning, hybrid delivery methods. UDL enhances curriculum flexibility.	Integrate UDL into teacher training programs, provide targeted professional development, improve administrative support, and allocate resources for inclusive PE.	Highlights systemic gaps in educator training for students with VIAD. Demonstrates UDL's role in addressing learner variability, offering evidence for inclusive policy reforms in PE and special education.
(van Munster et al., 2019)	UDL strategies for accessibility/engagement in PE (inferred: Focus on identifying UDL implementation alongside differentiated practices).	To identify pedagogical approaches used by PE teachers to accommodate students with disabilities (SWDs) and describe the principles guiding these practices.	Qualitative case study: Non-participant observations (72 classes), semi-structured interviews, thematic analysis. Triangulation via member checking and peer debriefing.	Not applicable (observational study; no intervention tested).	1. Three approaches identified: Normalized Instruction (no differentiation), Differentiated Instruction (tailored adaptations), and Universally Designed Instruction (UDL principles). 2. Differentiated Instruction was most prevalent, but UDL strategies were observed (e.g., varied equipment, multisensory engagement). 3. UDL proactively addressed variability; DI responded reactively to individual needs.	1. UDL and DI are complementary: UDL provides broad accessibility, while DI addresses specific needs. 2. Prioritize UDL for proactive design but use DI for individualized adjustments. 3. Train teachers to blend both approaches contextually.	Demonstrates the complementary roles of UDL and DI in inclusive PE, offering a framework for balancing proactive design with reactive adaptations.
(López Ibáñez et al., 2023)	UDL strategies for accessibility/engagement in PE (inferred: Focus on integrating UDL and ICT to design inclusive PE programs).	To design and validate an intervention program for inclusive PE using UDL and ICT for students with intellectual disabilities.	Evaluative research design: Expert judgment validation (Kappa coefficient, Cronbach's alpha), descriptive and inferential analysis (SPSS v24).	"Educación Física Fácil: deporte y salud" program: ICT tools (tablets, virtual reality, Wii Sports) aligned with UDL principles (multiple representations, engagement strategies).	1. High inter-rater agreement (Kappa: 0.66–0.87; $p < .05$). 2. Validated instrument reliability ($\alpha = .726$). 3. Strong expert consensus on program dimensions (median $\geq 3.5/4$).	1. UDL and ICT integration enhances accessibility and engagement in PE for students with disabilities. 2. Prioritize resource availability and teacher training for ICT implementation. 3. Use validated programs to bridge policy-practice gaps in inclusive education.	Provides a validated UDL-ICT intervention model for inclusive PE, addressing a critical gap in practical, technology-driven strategies for students with intellectual disabilities.

Table 2 (continued)

Author(s)	Category of Study	Objective of Study	Methodology of Study	Intervention Adaptation Strategy	Key Results of Study	Conclusion Recommendations of Study	Added Value of this Study
(Kennedy & Yun, 2019)	UDL strategies for accessibility/engagement in PE (inferred: Focus on UDL as a proactive curriculum tool to enhance inclusion).	To explain UDL as a curriculum development framework for inclusive PE and demonstrate its alignment with national standards.	Qualitative : Conceptual/theoretical analysis: Literature review, curriculum alignment with UDL principles, and illustrative examples (e.g., case study of student with cerebral palsy).	UDL-based curriculum framework integrating goals, methods, materials, and assessments aligned with SHAPE America standards.	1. UDL principles align with national PE standards to promote inclusive practices. 2. Proactive curriculum design reduces reactive modifications. 3. UDL fosters "expert learners" through flexible goals and assessments.	1. UDL enhances inclusive PE by embedding accessibility into curriculum design. 2. Prioritize proactive planning over reactive modifications. 3. Align UDL with national standards to foster lifelong physical activity.	Bridges UDL theory and PE practice, offering a structured framework for curriculum development to address inclusion gaps in teacher training and policy.
(Taunton et al., 2017)	UDL strategies for accessibility/engagement in PE (inferred from focus on inclusive, universally designed motor skill interventions).	To examine the effects of a 6-week SKIP-UDL intervention on remedial FMS delays in children with/without disabilities in an inclusive Head Start setting.	Experimental design: Pretest-posttest control group. - Random assignment by classroom. - ANOVA with repeated measures (time $\times$ group interaction). - Intervention fidelity checks (95% adherence; inter-observer agreement = 94%).	SKIP-UDL intervention: - 6-week, 360-minute program (30 min/session, 2x/week). - Merged UDL principles (equipment diversity, child-driven choices, least-to-most prompting) with SKIP pedagogy (structured stations, high practice trials). - Contrasted with control group ("business as usual" unstructured play).	- Significant FMS improvement in SKIP-UDL groups ($\eta^2 = 0.67$ interaction effect). - SKIP-UDL (no disability): +25.8 raw score points (16th $\rightarrow$ 73rd percentile). - SKIP-UDL (disability): +15.7 points (16th $\rightarrow$ 50th percentile). - No improvement in control group.	- Structured UDL-based interventions effectively remediate FMS delays for inclusive early childhood settings. - Head Start programs should adopt structured, UDL-aligned motor skill curricula. - Longer intervention durations (9–12 weeks) may enhance outcomes for children with disabilities.	First empirical validation of UDL in motor skill interventions for inclusive early childhood settings. Demonstrates UDL's efficacy in bridging FMS gaps between children with/without disabilities. Provides a model for scalable, equitable PE curricula in socioeconomically disadvantaged populations.

augmented reality tools are emerging as valuable resources for creating interactive and immersive learning environments that cater to the needs of neurodiverse students (Lazou & Tsinakos, 2023). Policy initiatives that support the integration of these innovative technologies have the potential to transform the delivery of physical education, making it more responsive and inclusive (Raza, 2024). The interdisciplinary nature of current research underscores that successful inclusion requires not only pedagogical innovation but also systemic change at the policy level (Rosa et al., 2025). Collaborative models involving educators, technology experts, and policymakers are essential to realizing this vision (Morrison & Gledlie, 2019).

Public Policy and Resource Allocation

Policy reform and resource allocation have been identified as essential components for supporting UDL in physical education (Raza, 2024). National and regional policies, when effectively implemented, can create frameworks that empower teachers to apply inclusive methodologies consistently (Lloyd et al., 2024). Recent literature emphasizes the critical need for policy that not only advocates inclusion but also provides the necessary funding and structural support for comprehensive teacher training (Kulal et al., 2024). Studies indicate that countries with robust professional development initiatives show higher levels of teacher confidence and competence in inclusive education settings (Capp, 2020). Moreover, the digital divide remains a persistent challenge, as schools with insufficient technological resources are less able to leverage UDL strategies effectively (Basham et al., 2020). Research exploring the integration of emerging technologies, such as AI and AR, into physical education suggests that these tools can revolutionize traditional pedagogies by offering personalized learning experiences (Lazou & Tsinakos, 2023). Furthermore, interdisciplinary models that combine educational neuroscience with AI are beginning to inform the development of adaptive learning environments (Rosa et al., 2025). Empirical findings also reveal that collaborative partnerships between educational institutions and community organizations facilitate the implementation of inclusive policies (Morrison & Gledlie, 2019). The synthesis of policy, technology, and teacher training research underscores the potential for a holistic approach to bridge the gaps in inclusive physical education (Block et al., 2021).

Emerging interdisciplinary models now offer promising avenues to further bridge the gaps between teacher training, policy,

and practice in inclusive physical education (Raza, 2024). Integrative approaches that combine insights from educational neuroscience, technology, and social sciences are redefining what is possible in creating equitable learning environments (Rosa et al., 2025). Research from multiple studies confirms that collaboration between schools, communities, and workplaces not only enhances learning outcomes but also fosters sustainable inclusive practices (Morrison & Gleddie, 2019). Empirical findings indicate that teacher training programs incorporating interdisciplinary content are more successful in preparing educators to meet the diverse needs of their students (Capp, 2020). Furthermore, the researchers shows that when policies explicitly promote partnerships across sectors, the overall quality of physical education programs improves markedly (Kulal et al., 2024). Case studies reveal that such collaborative frameworks facilitate the adoption of innovative instructional strategies, including UDL and DI, thereby enhancing student engagement and learning efficacy (Griful-Freixenet et al., 2020). In addition, the integration of emerging digital technologies within these models provides teachers with powerful tools to assess and adapt to individual student needs (Song et al., 2025). The convergence of policy support, technological innovation, and robust teacher training is thus essential for advancing inclusive physical education on a global scale (Block et al., 2021). This synthesis of research findings and best practices offers a roadmap for future initiatives aimed at achieving systemic change in the field (Loyd et al., 2024).

Conclusion

This systematic review underscores the transformative potential of Universal Design for Learning (UDL) in fostering equitable and inclusive physical education (PE) environments for students with disabilities. By synthesizing empirical evidence from diverse global contexts, the study highlights that UDL-aligned strategies—grounded in flexible engagement, representation, and action/expression—significantly enhance motor skill development, participation rates, and social inclusion. In OECD settings, adaptive equipment, multimodal instruction, and collaborative tasks drove measurable improvements, with motor skill gains and participation increases of up to 50%. However, persistent disparities in non-OECD regions, exacerbated by cultural stigma, infrastructural deficits, and inconsistent teacher training, reveal the uneven penetration of UDL principles. Critical barriers, such as inadequate professional development (40% of OECD educators reported insufficient preparation) and resource scarcity, underscore the need for systemic reforms. The integration of emerging technologies, including AI and virtual reality, emerges as a promising avenue to bridge accessibility gaps and personalize learning experiences. To translate UDL's theoretical promise into universal practice, policymakers and educators must prioritize mandatory UDL training in teacher education programs, equitable resource distribution, and cross-sector collaborations. These efforts must be coupled with institutional support to ensure pedagogical innovations align with localized needs, thereby mitigating contextual challenges and fostering sustainable inclusion.

While this review advances understanding of UDL's efficacy in PE, critical gaps warrant further investigation. First,

longitudinal studies are imperative to assess the durability of motor skill and social inclusion gains, particularly in under-resourced and non-OECD contexts. Second, mixed-methods research should explore the interplay between UDL and cultural factors, such as stigma or gender norms, to develop context-specific implementation frameworks. Third, the role of technology—AI, gamification, and immersive tools—in scaling UDL practices demands rigorous evaluation, including cost-benefit analyses and ethical considerations in low-income settings. Additionally, standardized metrics for assessing UDL outcomes (e.g., universal participation rubrics, motor skill benchmarks) must be developed to enhance comparability across studies. Future work should also examine systemic enablers, such as policy coherence and intersectoral partnerships, to identify scalable models for institutionalizing UDL. Finally, interdisciplinary collaborations between educators, neuroscientists, and technologists could pioneer adaptive learning environments that integrate UDL with cutting-edge insights from educational neuroscience. Addressing these priorities will not only refine UDL's theoretical foundations but also empower global stakeholders to dismantle barriers to inclusion, ensuring all students thrive in dynamic, equitable PE settings.

Conflict of Interest

Authors declare that they have no conflict of interest related to the content of this manuscript.

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Виявлення впливу універсального дизайну навчання на інклюзію учнів з інвалідністю у фізичному вихованні: Систематичний огляд

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 14 с., 2 табл., 1 рис., 46 джерел.

Історія питання. Універсальний дизайн навчання (УДН) пропонує трансформаційну основу для сприяння рівності в інклюзивному фізичному вихованні (ФВ), задовольняючи різноманітні потреби учнів з інвалідністю через гнучке залучення, репрезентацію та дії/експресію. Попри теоретичну відповідність проактивній інклюзії, в усьому світі зберігаються розбіжності у впровадженні цього підходу, на які впливають підготовленість вчителів, обмеженість ресурсів і культурний контекст.

Мета дослідження. Основною метою цього дослідження було оцінити шляхи подолання зазначених контекстуальних бар'єрів через використання стратегій, відповідних до принципів УДН.

Матеріали та методи. У представленому систематичному огляді проведена оцінка ефективності педагогічних стратегій, відповідних до принципів УДН, щодо розширення участі, розвитку моторики, соціальної інклюзії та залучення до занять фізичною культурою учнів з інвалідністю, які навчаються за системою освіти К-12. Комплексний пошук у наукометричних базах Scopus (n = 1,183) та Web of Science (n = 823) виявив 2,006 досліджень, з яких було відібрано 13 високоякісних статей шляхом ретельного відбору, оцінювання упередженості (Cochrane RoB 2.0, шкала Ньюкасл-Оттава) та подвійного незалежного вилучення.

Результати. За результатами синтезу змішаних методів встановлено, що інтервенції із застосуванням УДН значно покращили розвиток рухових навичок ($\eta^2 = 0.67$) та рівень залученості (до 50%) в контексті ОЕСР, що зумовлено використанням адаптивного обладнання та мультимодальних засобів навчання. Соціальна інклюзія зросла завдяки виконанню спільних завдань (30% приросту за рахунок взаємодії з однолітками), однак у країнах, що не є членами ОЕСР, збереглася прихована ексклюзія через стигматизацію та інфраструктурні прогалини. До ключових бар'єрів належать непослідовна підготовка викладачів (40% освітян країн ОЕСР повідомили про неналежну професійну підготовку) та брак ресурсів, зокрема в школах з недостатнім фінансуванням. Інтеграція технологій (штучний інтелект, віртуальна реальність) продемонструвала потенціал у персоналізації навчання та подоланні прогалин у доступності. Отримані дані підкреслюють необхідність проведення системних реформ: забезпечення обов'язкової підготовки із застосування УДН у педагогічній освіті, розподіл ресурсів відповідно до політичних рішень, а також міжсекторальна співпраця для розширення інклюзивних практик.

Висновки. Цей огляд підтверджує доцільність впровадження лонгітюдних досліджень і стандартизованих показників з метою усунення методологічних обмежень, підкреслюючи роль УДН у досягненні рівноправного, сталого середовища для розвитку фізичного виховання в глобальному масштабі. Узгоджуючи педагогічні інновації з інституціональною підтримкою, УДН сприяє подоланню контекстуальних бар'єрів, забезпечуючи розвиток усіх учнів у динамічних та інклюзивних умовах.

Ключові слова: моторика, розвиток, підготовка вчителів, соціальна інклюзія.

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The Impact of Adaptive Physical Education on the Physical and Cognitive Development of Children with Special Needs: A Literature Review

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Abstract

Objectives. This study aimed to conduct a literature review to examine the effects of adaptive physical education on the cognitive and physical development of children with special needs (CSN). Adaptive physical education enhances motor skills, physical health, and cognitive function in people with physical, sensory, or intellectual disabilities.

Materials and methods. A literature review is the research approach used, which looks at several pertinent empirical and theoretical studies conducted over the last five years, from 2019 to 2024, that provide guidance on the optimal method of educating students. The electronic searches have been performed using Scopus, Web of Science, Google Scholar, and PubMed. This review of the study investigates the ways in which physical education might enhance students' motor skills, physical fitness, and cognitive and emotional development. This study also emphasizes the difficulties in implementing Physical Education (PE) into practice, such as inadequate facilities and unsupportive attitudes toward the topic.

Results. The study's findings demonstrate that adaptive physical education helps children with special needs to improve their balance, muscular strength, motor coordination, and aerobic capacity. This program also improves cognitive skills, including social skills, working memory, and focus. This article also offers suggestions for educators and legislators to increase the efficacy of adaptive physical education (APE) in inclusive curriculum.

Conclusions. Adaptive physical education has been considered to be a successful strategy for promoting the cognitive and physical development of children with special needs. It is recommended that programs are implemented according to individual requirements in order to maximize the advantages.

Keywords: adaptive physical development, children with special needs, physical development, cognitive development, literature review.

Introduction

Children with special needs (CSN) benefit significantly from adaptive physical education (APE), which supports their cognitive and physical development. Due to their sensorimotor, neurological, or cerebral deficiencies, children with special needs often face challenges in their physical and cognitive activities (Sherrill, 2004). The purpose of the APE program is to enhance a person's physical, motor, and cognitive capacities by offering a movement experience

that is suitable for their abilities (Hutzler & Sherrill, 2007). In addition to increasing physical fitness, APE enhances executive function, motor coordination, and social and emotional abilities via a methodical, needs-based approach (Willoughby & Hudson, 2023). The utilization of a digitally based physical education (PE) curriculum in primary schools is investigated in this research. Despite the fact that 74% of instructors perceive advantages, issues include a lack of training and insufficient infrastructure. For successful implementation and student growth, recommendations include enhancing infrastructure, educating educators, and guaranteeing fair access to technology (Indarto et al., 2024).

In terms of physiology, CSN's participation in organized exercise enhances muscular strength, cardiorespiratory

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endurance, and flexibility all of which are critical for their everyday mobility and independence (Winnick & Porretta, 2016). According to this research, children with special needs benefit from typical sports treatment in terms of their motor abilities. To improve total physical fitness in children with exceptional needs, further study should take psychological and psychosocial elements into account (Nurhidayat et al., 2023). APE has been shown in several studies to enhance motor control, balance, and posture, particularly in children with developmental abnormalities, including autism spectrum disorder (ASD) and cerebral palsy (Westendorp et al., 2011). Furthermore, it has been shown that an exercise program based on modified High-Intensity Interval Training (HIIT) may improve aerobic capacity and lower the risk of obesity, which is common in this group (Pan et al., 2017). The goals of exercise programs are to enhance cognitive function, motor abilities, and physical fitness (Nugroho et al., 2024). According to research, both cardiovascular endurance and muscular strength are enhanced by resistance and aerobic exercise (Fachrezzy et al., 2023). Children with exceptional disabilities benefit significantly from game-based activities that improve their social skills and motor coordination (Dapp et al., 2021). Additionally, modified High-Intensity Interval Training (HIIT) lowers the risk of obesity and increases aerobic capacity in children with special needs (Westendorp et al., 2011). This research examines 15 publications on holistic education in physical education to improve whole-child development via efficient teaching techniques. It suggests a conceptual framework that integrates body, mind, and spirit (Syaukani et al., 2023). Strategic interventions are needed to promote sports participation and health education (Syaukani et al., 2024).

APE may enhance executive functions, such as working memory, attention, and problem-solving abilities, from a cognitive standpoint. According to a study by Gunzenhauser & Nückles (2021) physical exercise that requires strategy and coordination might enhance brain plasticity and neural connection, both of which support CSN's cognitive development. Participating in adaptively planned physical activities also enhances emotional control and self-regulation, which is crucial for children with developmental disorders like ASD and Attention Deficit Hyperactivity Disorder (ADHD) (Memari et al., 2013).

The absence of qualified teaching personnel, inadequate facilities, and instructors' ignorance of how to adapt activities to meet the unique requirements of CSN are just a few of the obstacles that currently hinder APE's adoption in the educational setting (Block & Obrusnikova, 2007). Thus, the purpose of this evaluation of the research is to thoroughly examine how APE affects CSN's physical and cognitive development and investigate implementation techniques that might increase the program's efficacy in the classroom.

Materials and methods

Search Profile and Database

The influence of adaptive physical education on the cognitive and physical development of children with special needs is examined in this research using a literature review methodology. To have a thorough grasp, this approach is utilized to locate, examine, and synthesize different scientific

publications. Using keywords like "adaptive physical education," "physical development of children with special needs," and "cognitive development," literature searches were carried out using databases like Google Scholar, ScienceDirect, PubMed, and Web of Science. The search process was divided into four stages (Preferred Reporting Items for Systematic Reviews and Meta-Analyses): identification (finding 500 related articles from various sources), screening (removing 150 duplicates), eligibility (120 articles meeting the criteria after evaluation of research methodologies and results), and inclusion (only 30 articles that passed the final selection based on the PEDro scale, which is available for free online (<https://www.pedro.org.au/english/downloads/pedro-scale/>) and has been translated into seven languages in figure 1).

The PRISMA Statement (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) for meta-analysis, which encompasses the phases of Identification, Screening, Feasibility, and Inclusion (Page et al., 2021) (figure 1).

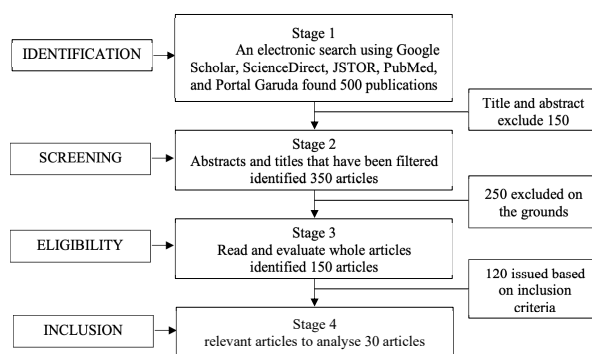


Fig. 1. Search procedure flow diagram

When conducting a literature review, inclusion and exclusion criteria are established to ensure that the literature is used for relevance in accordance with the research topic. Table 1 shows the inclusion and exclusivity criteria applied to research on the impact of adaptive physical education on the physical and cognitive development of children with special needs through a literature review. As illustrated in the flow chart (Figure 1), a total sample of 30 articles was obtained from a total of 500 articles that adhered to the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) (Page et al., 2021).

Methodological Evaluation of Quality

According to Moseley et al. (2020) articles with a score of 8–11 are considered high quality, a score of 4–7 is considered moderate, and a score below 4 is considered low. The methodology was evaluated using the 11 criteria of PEDro (Physiotherapy Evidence Database), which helps users overcome time constraints and critical thinking skills and facilitates the integration of research into clinical practice.

Procedure for Data Analysis

The following steps make up the systematic data analysis process in this literature review: First, the literature is found

Table 1. A comprehensive assessment of adaptive physical education on the cognitive and physical development of children with special needs inclusion and exclusion criteria

Classification	Criteria	
	Inclusion	Exclusive
Study Type	Studies that examine the effects of adapted physical education on the cognitive and/or physical development of children with special needs (CSN) by correlational, experimental, and quasi-experimental methods.	Descriptive research does not examine the link between CSN development and adaptive physical education.
Participants	Children aged 6 to 18 who participate in adaptive physical education programs have unique needs (such as autism, ADHD, blindness, hearing, or disability).	Studies that targeted the adult population (>18 years old) or included individuals without special needs
Intervention	Programs for adaptive physical education that are focused on systematic physical activity, such as those that include games, exercises, and motor training.	Studies that solely looked at physical therapy without a physical education component or that did not use adaptive physical education as the primary intervention.
Variables Examined	Cognitive (executive function, attention, memory) and/or physical (balance, coordination, strength, endurance) development	Research that excludes physical or cognitive development and only focuses on social-emotional or psychosocial factors
Type of Publication	Articles published in peer-reviewed international conference proceedings or scientific journals that are indexed by Scopus or Web of Science.	Viewpoints that are not supported by actual research, popular novels, technical reports, or non-peer-reviewed publications.
Language	Articles written in either Indonesian or English	Articles without official translations are written in languages other than English or Indonesian

and chosen using academic databases like Scopus, Web of Science, and Google Scholar with keywords related to adaptive physical education and the development of children with special needs; Second, screening is done based on the research method, relevance, and year of publication (last 5 years); Third, data synthesis employs qualitative meta-synthesis to find patterns of findings; Fourth, comparative analysis compares research results based on the type of disability and intervention method; and finally, the results are interpreted to highlight the theoretical and practical implications in adaptive physical education.

Limitations of the Research

The scope of the research includes adaptive physical education programs created for children with various types of disabilities, such as the visually impaired, deaf, visually impaired, and cerebral palsy, taking into account the factors of learning methods, exercise intensity, and pedagogical approaches. The limitations of this study are concentrated on analyzing the impact of adaptive physical education on the physical and cognitive development of children with special needs through a literature review.

Results

The Number of Results Examined

The following chart displays the total number of publications in the chosen period. The PEDro 11 scale was used to assess the quality of the analyzed articles. The literature review includes research on the impact of adaptive physical education on the cognitive and physical development of children with special needs (table 2). The literature searches are carried out electronically through

Google Scholar, ScienceDirect, PubMed, and Web of Science using the PRISMA method.

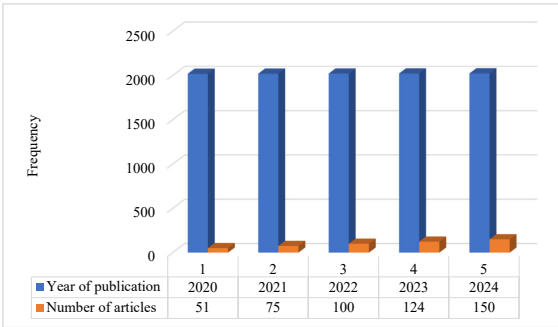


Fig. 2. Annual growth in the number of articles

Figure 2 shows the evolution of the number of publications over different periods. This includes a noticeable increase in scientific output from 2020 (51 articles), 2021 (75 articles), 2022 (100 articles), 2023 (124 articles), and 2024 (150 articles). The literature indicates that the thematic analysis that can be applied in physical education learning is shown in the figure above, which consists of thirty studies. Research on strategies to improve physical education learning improves students' health, physical activity, active lifestyle, and physical fitness.

Results of Exercise Significance

Regardless of gender, all 30 of the chosen and examined publications demonstrated noteworthy findings about the effects of adaptive physical education on the cognitive and physical development of children with special needs.

Table 2. PEDro scale for population and research design

N.	Study	PEDro scale											Total
		1	2	3	4	5	6	7	8	9	10	11	
1	(Du et al., 2024)	1	1	0	1	0	0	0	1	0	0	1	5
2	(Meijers et al., 2024)	1	1	0	1	0	0	0	1	0	1	1	6
3	(Miray Sümer Dodur & Çalışkan, 2024)	1	1	0	1	0	0	0	1	0	1	1	6
4	(Peltokorpi et al., 2024)	1	1	0	1	0	0	0	1	0	1	1	6
5	(Vargas et al., 2024)	1	1	0	1	0	0	0	1	0	1	1	6
6	(Stark et al., 2024)	1	1	0	1	0	0	0	1	0	1	1	6
7	(R. Yang et al., 2024)	1	0	0	1	0	0	0	1	0	1	1	5
8	(Then & Pohlmann-rother, 2023)	1	1	0	1	0	0	0	1	0	0	1	5
9	(Habbak & Khodeir, 2023)	1	1	0	1	0	0	0	1	0	1	0	5
10	(Labbe, Delphine et al., 2023)	1	0	0	1	0	0	0	1	0	1	1	5
11	(Haerens et al., 2023)	1	1	0	1	0	0	0	1	0	0	1	5
12	(Pushkarenko et al., 2023)	1	1	0	1	0	0	0	1	0	0	1	5
13	(Tarantino et al., 2022)	1	1	0	1	0	0	0	1	0	1	1	6
14	(Sonnenschein et al., 2022)	1	1	0	1	0	0	0	1	0	0	1	5
15	(Atkins et al., 2022)	1	1	0	1	0	0	0	1	0	1	1	6
16	(Schoop-kasteler, 2022)	1	1	0	1	0	0	0	1	0	1	1	6
17	(Oki et al., 2022)	1	1	0	1	0	0	0	1	0	1	1	6
18	(Health, 2022)	1	1	0	1	0	0	0	1	0	0	1	5
19	(Putten et al., 2022)	1	1	0	1	0	0	0	1	0	1	1	6
20	(Roorda et al., 2021)	1	1	0	1	0	0	0	1	0	1	1	6
21	(W. Yang et al., 2021)	1	1	0	1	0	0	0	1	0	1	1	6
22	(Kok et al., 2021)	1	1	0	1	0	0	0	1	0	1	1	6
23	(Guo et al., 2021)	1	1	0	1	0	0	0	1	0	1	1	6
24	(Chinwendu et al., 2021)	1	0	0	1	0	0	0	1	0	1	1	5
25	(Jebril & Chen, 2021)	1	1	0	1	0	0	0	1	0	0	1	5
26	(Müller et al., 2021)	1	1	0	1	0	0	0	1	0	1	0	5
27	(Francisco et al., 2020)	1	0	0	1	0	0	0	1	0	1	1	5
28	(Dhiman et al., 2020)	1	1	0	1	0	0	0	1	0	0	1	5
29	(Sheppard & Wieman, 2020)	1	1	0	1	0	0	0	1	0	0	1	5
30	(Siegel et al., 2020)	1	1	0	1	0	0	0	1	0	1	1	6

Note: (1) Eligibility criteria; (2) Random allocation; (3) Allocation concealment; (4) Baseline comparability; (5) Blind participants; (6) Blind assessor; (7) Blind Therapist; (9) Intention to treat analysis; (10) Between-group comparisons; and (11) Point measure variability are available at https://pedro.org.au/wp-content/uploads/PEDro_scale.pdf

The reviewed 30 studies highlight key aspects of adaptive physical education. The research findings from 30 articles highlight the significant impact of adaptive physical education on the physical and cognitive development of children with special needs. Various studies demonstrate that physically active learning (PAL) programs and

structured motor activities enhance engagement, improve motor skills, and foster cognitive and social development. Several interventions, such as bodily-tactile approaches, multisensory environments, and classroom modifications, have been shown to facilitate better learning outcomes and emotional resilience in children with disabilities. Moreover,

Table 3. Features and findings of the literature review on the effects of adaptive physical education on the cognitive and physical development of children with special needs

Author, Year	Topic	Sample	Result
(Du et al., 2024)	The impact of cognitive reappraisal on emotion recognition in mothers of children with special needs.	Mothers of children with special needs and mothers of typically developing children	Mothers of children with special needs detect negative emotions quickly, with bias. Cognitive reappraisal improves surprise recognition and reduces anger bias
(Meijers et al., 2024)	Implementation of a Physically Active Learning (PAL) program in special-needs schools for children with learning disorders.	37 children from two special-needs schools	PAL had a 95%+ implementation rate, improved on-task behavior (79%+), and 43% moderate-to-vigorous PA. Motor skills and fitness correlated with engagement.
(Miray Sümer Dodur & Çalışkan, 2024)	This study examined the relationships between parent-to-parent support perception, quality of life, and parent-child relationships parents of children with special needs.	235 Turkish parents of children with special needs	Quality of life partially mediates relationships, and enhancing parent-to-parent support improves it, strengthening parent-child bonds
(Peltokorpi et al., 2024)	The study explores bodily-tactile early intervention effects on interactional reciprocity between sighted mothers and one-year-old children with visual impairment and additional disabilities (VIAD)	Three mother-child pairs participated in an eight-hour video-based multiple-case study	The intervention improved interactional reciprocity, as mothers used more bodily-tactile modalities and treated their children's movements as meaningful turns in interaction
(Vargas et al., 2024)	The study explores how reading frequency and medium affect text comprehension in primary students, including those with and without special education needs (SEN).	2,289 Spanish students (fourth to sixth grade), including 212 with SEN.	Leisure print reading positively impacts comprehension, while frequent academic digital reading negatively affects it, regardless of SEN status
(Stark et al., 2024)	Interdisciplinary collaboration between social-emotional learning (SEL) and special education research to enhance inclusion in schools.	Conceptual discussion, no empirical data	Inclusion needs proactive efforts, clear roles, universal benefits, and commitment. Interdisciplinary research helps overcome barriers and enhance inclusive policies.
(R. Yang et al., 2024)	Sedation considerations for people with special needs (PSN) in dentistry.	Review of various sedative agents and their implications for PSN.	Effective sedation requires assessing medical comorbidities, risks, benefits, and patient cooperativeness to determine appropriate agents and administration routes
(Then & Pohlmann-rother, 2023)	A systematic review of research on the transition to formal schooling for children with disabilities, based on ecological systems theory and an inclusive transition model.	55 studies using various methods, primarily interviews and questionnaires, focusing on parents, teachers, and service providers	Findings highlight shared perspectives on barriers and facilitators but reveal a lack of research on children's views, peer interactions, and broader social conditions
(Habbak & Khodeir, 2023)	Sensitivity of children with autism to interior space elements and their impact on skill development through multi-sensory rooms.	Children with autism in rehabilitation centers	Children with autism are most sensitive to light, which can be utilized in multi-sensory rooms to enhance their skills.
(Labbe, Delphine et al., 2023)	The study explores the experiences of individuals with disabilities in online adaptive leisure-time physical activity (LTPA) and its health impacts.	Semi-structured interviews with 10 participants and a survey of 104 individuals engaged in online adaptive LTPA	Online LTPA provides physical, emotional, and social benefits. Key factors include staff attitude, adaptability, and equipment access.

Table 3 (continued)

Author, Year	Topic	Sample	Result
(Haerens et al., 2023)	The study examines the combination of competence-supportive and controlling teaching styles in PE and their impact on students' motivation.	1,107 students participated	Competence support fostered positive motivation, while external and internal control led to negative outcomes. The "high competence-support, low control" profile was most adaptive, whereas "low competence-support, very high control" was most maladaptive
(Pushkarenko et al., 2023)	This study explores physical literacy (PL) from the experiential perspective of individuals with disabilities, emphasizing its role in fostering autonomy and belonging.	Thirteen individuals with disabilities participated in two focus groups, with data analyzed thematically.	Three themes emerged: (1) imagine the possibilities, (2) dance like nobody's watching, and (3) no wrong way to move. PL was valued for exploration, learning, and social interaction.
(Tarantino et al., 2022)	Teachers' attitudes toward including children with special educational needs and disabilities (SEND) in physical education.	Studies analyzed in a mixed-methods systematic review and meta-analysis	Teachers generally have favorable attitudes, influenced by experience, knowledge, preparation, years of teaching, type/degree of SEND, and support.
(Sonnenschein et al., 2022)	Parental views on distance learning for students with disabilities during COVID-19.	153 parents of PK-12 students receiving special education services	Limited special education, high reliance on adults for virtual learning, and parental difficulties balancing support with work and childcare
(Atkins et al., 2022)	Nursing students' engagement with children with special mental and physical disabilities.	28 undergraduate nursing students in a community-based respite care program	Benefits: cognitive growth, rewarding relationships, stress relief. Challenges: emotional discomfort, behavior management, expectations. Faculty support and community collaboration improve engagement
(Schoop-kasteler, 2022)	The study examines the sociometric status of students with intellectual disabilities (ID) in special needs schools and its relationship with social skills.	1,068 students with ID ($M = 11.98$ years, $SD = 3.74$; 31.5% female) assessed by school staff.	Many students were perceived as neglected. Accepted students had higher social skills, while rejected students had lower social skills than average students.
(Oki et al., 2022)	Floor projection feedback system for spatial-temporal cognition in adolescents with neurodevelopmental disorders (NDs) during physical activity.	Adolescents with NDs engaged in organized physical activities	The algorithm encouraged individuals to maintain close group proximity rather than equal spacing while walking, demonstrating its effectiveness in different organized physical activities.
(Health, 2022)	The disparity between under-5 mortality rates and the likelihood of disability before age five, highlighting inadequate disability funding.	Global data on child disability (377.2 per 1000 live births) vs. under-5 mortality (38.2 per 1000 live births) in 2019.	Disability funding declined by 11.4% (2007–2016), with only 2% of \$79.1 billion allocated to disabilities. Urgent policy and funding reforms are needed to address inequalities by 2030.
(Putten et al., 2022)	Measurement and analysis challenges in studying young children with significant cognitive and motor developmental delays.	45 children (6 months–4 years) from Belgium and the Netherlands.	Research confirmed the complexity of disabilities, contextual challenges, and measurement difficulties, highlighting the need for creativity, perseverance, and modesty in generalizing findings
(Roorda et al., 2021)	Differences in student-teacher relationship quality and school engagement between boys in regular and special education for autism spectrum disorders (ASD).	182 boys from regular education and 113 boys from special education for ASD (grades 3–6).	Boys with ASD reported more conflict and lower engagement. Conflict had a stronger negative impact on engagement in special education

Table 3 (continued)

Author, Year	Topic	Sample	Result
(W. Yang et al., 2021)	The association between physical activity (PA) and mental health in children with special educational needs (SEN).	Systematic review of 18 studies (2010–2021) meeting inclusion criteria with quality ratings $\geq 60\%$.	PA improves psychological well-being, reduces anxiety and fatigue; unstructured PA has the strongest effects, while structured PA is most beneficial.
(Kok et al., 2021)	Effects of explicit vs. implicit instructions and feedback on motor learning and perceived competence in students with special educational needs.	9-to-13-year-old students practicing a balancing task in physical education	Performance and competence improved; verbal working memory influenced learning outcomes, but visuospatial memory did not. Instruction should align with verbal working memory capacity.
(Guo et al., 2021)	Examined early childhood special education (ECSE) teachers' self-efficacy in teaching children with and without disabilities and its impact on children's print knowledge.	73 ECSE teachers, 837 preschool children.	Teachers felt less self-efficacious with children with disabilities, especially autism. Higher self-efficacy predicted better print knowledge, but disability status did not moderate this relation
(Chinwendu et al., 2021)	The study assessed blended Rational Emotive Occupational Health Coaching (bREOHC) effectiveness in reducing occupational stress among teachers of children with special education needs.	A total of 83 teachers from inclusive and specialized schools in Abia State, Nigeria, participated in a group-randomized waitlist control trial	The bREOHC group showed significantly reduced stress levels post-intervention and at follow-up, with high participant satisfaction
(Jebril & Chen, 2021)	This study examines the architectural design of primary-school classrooms for intellectually disabled students, comparing them with classrooms for healthy students.	The research analyzes design specifications and environmental factors affecting students with intellectual disabilities	Five key architectural strategies are proposed, focusing on furniture, toilets, colors, materials, lighting, ventilation, and soft music.
(Müller et al., 2021)	Classroom peer effects on adaptive behaviors (conceptual, social, and practical skills) in students with intellectual disabilities (ID).	1125 students with ID (69% boys, mean age 11.30 years, SD = 3.75) in special needs schools.	Classroom peer effects were found for conceptual skills but not for social and practical skills
(Francisco et al., 2020)	The historical trajectory of special education, societal influences, and the effectiveness of inclusion.	A review of historical trends, special education laws, and key constructs	Inclusion challenges stem from unclear definitions, limited research, and awareness. Solutions include enhancing historical understanding, legal knowledge, and standardized implementation.
(Dhiman et al., 2020)	Mental health status and perceived strain among caregivers of children with special needs during COVID-19	264 caregivers completed an online survey	High depression (62.5%), anxiety (20.5%), and stress (36.4%) among caregivers. Increased strain and negative views on tele-rehabilitation worsened mental health.
(Sheppard & Wieman, 2020)	Alignment of special education and mathematics education in inclusive classrooms, focusing on teacher expertise in posing mathematical questions	Teacher educators from mathematics and special education	Significant differences in rankings of expertise, particularly in knowing individual students, teaching experience, students with disabilities, and mathematical content knowledge, highlighting collaboration challenges
(Siegel et al., 2020)	Intellectual disability (ID/IDD) as a psychiatric disorder and risk factor, DSM-5 updates, assessment, and treatment of co-occurring psychiatric disorders	Children and adolescents with ID/IDD	Effective diagnosis and treatment require modifications in techniques, understanding behavioral etiologies, and applying psychosocial and medical interventions

A thorough description of every PEDro Scala item may be found at <https://pedro.org.au/english/resources/pedro-scale/> Microsoft Word - PEDro_scale.doc (accessed on December,27,2024). The highest possible score is 10

parental and teacher involvement plays a crucial role in fostering a supportive learning environment. Studies emphasize the importance of interdisciplinary collaboration in inclusive education, addressing barriers to learning, and optimizing assessment and treatment techniques for children with special needs.

Additionally, the findings suggest that structured physical activity benefits psychological well-being, reducing anxiety and fatigue while improving self-efficacy and adaptive behaviors. However, challenges persist, including limited research on student perspectives, disparities in funding for disability support, and the need for policy reforms to enhance inclusive education practices. Overall, the studies highlight the necessity of tailored educational and therapeutic approaches to maximize the potential of children with special needs.

Discussion

Several significant themes that highlighted the role of physical education in fostering an active and healthy lifestyle were found via a literature review using the PRISMA technique. The findings of the literature from the 30 publications examined highlight the following important points:

Enhancement of Motor Skills

According to the most recent research, adaptive physical education is a program that helps children with special needs develop their motor skills, including fine motor skills like grasping and gross motor skills like walking and jumping. It also helps children with special needs develop their balance, coordination, and muscle strength.

According to Chung et al. (2008) after 12 weeks of exercise, children with cerebral palsy who participated in adaptive physical education had improved balance and postural stability; Ryan et al. (2017) demonstrated that water therapy helped children with neurological disorders enhance their balance and coordination of movements significantly; and Goodway et al. (2019) reported that a specially designed play-based program was able to improve body coordination and reflexes in autistic children, while Pan et al. (2017) demonstrated that games like gymnastics and jumping rope enhanced their motor skills and social interaction. Muthengi et al. (2024) The study found that cognitive academic engagement was positively related to school completion intention and was crucial for preventing school dropouts.

Additionally, Dapp et al. (2021) emphasize that structured physical activities, like balance and coordination exercises, have a positive effect on motor control in children with physical limitations. D. Lee et al. (2016) also found that proprioceptive exercise and walking therapy can help children with motor disabilities improve their confidence and movement control. Adaptive physical education, with the proper intervention, can help children with special needs improve their body's balance, coordination, and control, which supports their independence in day-to-day life.

Impacts on Fitness Level

Children with special needs frequently have limited physical activity, which contributes to low physical fitness

and an increased risk of obesity and other health issues (Hutzler & Sherrill, 2007). As a result, programs that are tailored to the abilities of the children can have a substantial positive impact on their physical condition. Adaptive physical education programs are crucial in improving the cardiovascular endurance, muscle strength, and flexibility of children with special needs.

Güeita-Rodríguez et al. (2021) found that water-based therapy improved cardiovascular endurance, flexibility, and motor coordination in children with autism spectrum. Marzouki et al. (2022) found that an eight-week water-based exercise program improved aerobic capacity and muscle strength in children with autism. Activities like swimming and resistance training in the water help increase endurance without overloading the joints.

Additionally, Merino-Andrés et al. (2022) found that community-based strength training improved functional capacity and reduced fatigue in children with cerebral palsy. Abdullah and Putri (2025) found that the SETITI breathing exercise app for children with cerebral palsy is very accessible, easy to use, and motivates breathing exercises. It is advised to enhance the display choice with your favorite cartoons. Saadawi et al. (2025) also stated that community-based resilience training can improve the physical fitness of children with physical limitations.

Additionally, research by Ulrich et al. (2001) demonstrated that a 12-week treadmill-based exercise intervention significantly improved cardiovascular endurance and balance in children with Down syndrome, and Bahiraei et al. (2023) showed that children with Down syndrome who engage in adaptive aerobic exercise have an increase in cardiovascular endurance and flexibility. Activities like adaptive cycling, brisk walking, and specially designed games help increase a child's aerobic capacity without placing undue strain on the musculoskeletal system.

All things considered, adaptive physical education helps children with special needs become more physically active and lowers their risk of obesity and other health issues.

Improved Cognitive Function

Structured physical activity enhances blood flow and brain oxygenation, supporting a range of cognitive processes; physical activity-based interventions help improve attention, decision-making, and cognitive flexibility all of which are critical in both everyday life and educational settings; and adaptive physical education plays a significant role in improving the cognition of children with special needs, particularly concentration, executive function, and problem-solving.

Regular physical activity increases neuroplasticity, the brain's ability to form new connections, which supports children with attention deficit hyperactivity. Regular aerobic exercise also helps reduce impulsivity and improve academic focus. Ji et al. (2022) found that regular aerobic exercise had a significant impact on executive function in children with autism spectrum, including planning, self-control, and cognitive flexibility. The 12-week aerobics program improves task management skills, emotional control, and adapting to changing environments. Christiansen et al. (2019) found that children with ADHD increased working memory capacity and attention when they participated in adaptive exercise programs.

In addition, Northey et al. (2025) found that adaptive physical education enhances critical thinking abilities and information processing speed, while strategy-based and coordination exercises support analytical thinking and decision-making efficiency. Schmidt et al. (2018) found that complex motor exercises, including rhythmic gymnastics and coordination games, enhance the attention and memory capacity of children with dyslexia, while rhythmic and coordinated activity boosts cognitive nerve development.

Furthermore, exercise that gradually raises heart rate has a positive effect on neurotransmissions in the brain, which supports learning and cognitive development Liu et al. (2024) the moderate to high-intensity interval training program also improved memory function and thinking speed in children with special needs.

According to the study's overall findings, adaptive physical education improves the physical health of children with special needs and significantly improves their cognitive development. As a result, adaptive physical education programs should be planned methodically and consistently to maximize students' focus, executive function, and problem-solving abilities, which will ultimately improve their quality of life.

Psychosocial Effects

Adaptive physical education programs are crucial for improving the emotional well-being, social engagement, and self-confidence of children with special needs. These children frequently struggle with social interaction and experience higher levels of anxiety than other children. Using a specially designed approach, adaptive physical education provides an environment where children can improve their relationships with peers, develop social skills, and gain confidence.

K. Qi et al. (2024) added that interaction in these activities increases their comfort in the social environment, so their involvement in social activities outside of physical education sessions also increases. Lee and Vargo (2017) reported that children with autism who participated in group-based physical activity showed improved communication skills and social interaction. Physical activity in small groups helps them understand facial expressions and body language and respond better to communication.

Additionally, children who regularly participate in adaptive physical education have a more positive self-perception of their physical and social abilities. Goodwin and Watkinson (2000) stated that participation in adaptive physical education helps children feel welcome and increases social integration in school. An inclusive environment creates an enjoyable learning experience, promotes emotional well-being, and encourages participation in social and academic activities. Elshani et al. (2020) found that adaptive exercise helps reduce anxiety and increase the confidence of children with intellectual limitations.

Over the last ten years, research has shown that adaptive physical education helps children with special needs develop their character, confidence, and more positive social interactions in addition to their physical abilities.

The Role of Teachers and Learning Methods

Adaptive physical education ensures that all students can participate according to their abilities, so teachers must

be competent in modifying teaching strategies to support students' motor, cognitive, and social development. The success of adaptive physical education depends on an inclusive approach, appropriate learning methods, and teachers' abilities to adapt materials for students with special needs.

Research shows that special training for teachers improves the effectiveness of adapting adaptive physical education curriculum. Haegele and Sutherland (2015) highlighted that teachers who are trained are better equipped to create inclusive physical activities and customize learning to make it more meaningful. Colquitt et al. (2017) also discovered that instructional differentiation improves the motivation and engagement of students with special needs.

Martin Ginis et al. (2021) found that environmental adaptation, such as visual aids and multimodal instruction, helped students with sensory and motor limitations be more active in learning. Qi and Ha (2012) stated that flexible methods that support different learning styles increase student motivation. The Universal Design for Learning (UDL) approach has been proven to be effective in increasing student participation in adaptive physical education.

Anagnostopoulou et al. (2021) demonstrated that augmented reality and sensory devices improved the attention, motivation, and motor coordination of students with developmental disorders. Sharon et al., (2022) discovered that virtual reality can help students with intellectual disabilities better understand instruction and develop motor skills. Technology plays a significant role in improving the effectiveness of learning.

Furthermore, community-based learning has been shown to be successful. Saadawi et al. (2025) showed that student confidence and independence were raised by community engagement, such as participation in inclusion programs or partnerships with specialist coaches.

Because adaptive physical education relies on community participation, technology, UDL implementation, and teacher training, policies that encourage teacher competency development and innovative teaching strategies are desperately required.

Conclusions

Physically structured programs enhance motor skills, balance, coordination, and physical fitness; customized physical activity boosts self-esteem and social engagement; and from a cognitive perspective, adaptive physical education enhances concentration, problem-solving, and executive function, supporting academic achievement. The program's success depends on inclusive methods, teacher skills, and a supportive environment, making it an ideal tool for the holistic development of children with special needs, according to a literature review.

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Conflict of interest

According to the authors, this research has no conflicts of interest.

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Вплив адаптивного фізичного виховання на фізичний та когнітивний розвиток дітей з особливими потребами: Огляд літератури

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Мета дослідження. Мета цього дослідження полягала у проведенні огляду літератури щодо вивчення впливу адаптивного фізичного виховання на когнітивний та фізичний розвиток дітей з особливими потребами (ДОП). Адаптивне фізичне виховання сприяє покращенню рухових навичок, фізичного здоров'я та когнітивної функції у осіб з фізичними, сенсорними або інтелектуальними порушеннями.

Матеріали та методи. Огляд літератури є дослідницьким підходом, який застосовується для вивчення кількох відповідних емпіричних і теоретичних досліджень, проведених за останні п'ять років, з 2019 по 2024 роки, які надають рекомендації щодо визначення оптимального методу навчання студентів. Електронний пошук здійснювався із використанням наукометричних баз даних Scopus, Web of Science, Google Scholar та PubMed. Зазначений огляд дослідження вивчає способи, за допомогою яких заняття фізичним вихованням можуть поліпшити рухові навички, фізичну підготовленість, когнітивний та емоційний розвиток учнів. Дослідження також підкреслює труднощі щодо впровадження фізичного виховання (ФВ) у практичну діяльність, як-от недостатня матеріально-технічна база та несприятливе ставлення до цієї проблематики.

Результати. Результати дослідження демонструють, що адаптивне фізичне виховання сприяє покращенню рівноваги, м'язової сили, координації рухів та аеробної продуктивності у дітей з особливими потребами. Представлена програма також поліпшує когнітивні навички, включаючи соціальні навички, робочу пам'ять і концентрацію уваги. Дана стаття також містить пропозиції для освітян і законодавців щодо підвищення ефективності адаптивного фізичного виховання (АФВ) в рамках інклюзивної навчальної програми.

Висновки. Адаптивне фізичне виховання розглядається як ефективна стратегія, що сприяє когнітивному та фізичному розвитку дітей з особливими потребами. З метою максимізації переваг рекомендується впроваджувати програми відповідно до індивідуальних потреб.

Ключові слова: адаптивний фізичний розвиток, діти з особливими потребами, фізичний розвиток, когнітивний розвиток, огляд літератури.

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Review Article

Identifying Challenges and Opportunities in the Implementation of Mobile Learning in Physical Education: A Literature Review

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Abstract

Objectives. This study aimed to identify the challenges and opportunities in implementing mobile learning in physical education, focusing on its impact on learning effectiveness, student engagement, and teacher readiness.

Materials and methods. In this study, a systematic review of Scopus-indexed articles (2019–2024) on mobile learning in physical education was conducted. The study followed the PRISMA methodology, selecting 10 relevant articles from an initial dataset of 241,924. The analysis encompassed publication trends, research focus, methodologies, and citation rates to evaluate mobile learning's role in physical education.

Results. The findings indicate that mobile learning presents both challenges and opportunities in physical education. Key challenges include limited technological infrastructure, insufficient teacher training, and potential reductions in student physical activity due to inappropriate app use. However, using mobile learning technology offers significant benefits, such as increased accessibility, flexible learning options, gamification for motivation, and real-time performance tracking. Effective implementation of this learning technology requires appropriate teacher training, improved infrastructure, and careful selection of digital tools that enhance student engagement in physical activities.

Conclusions. Mobile learning has the potential to enhance physical education when integrated strategically. Overcoming technological and pedagogical barriers can maximize its benefits, making learning more interactive and effective.

Keywords: challenges, opportunities, mobile learning, physical education, literature review.

Introduction

With advancements in computing and multimedia, researchers are increasingly exploring the potential of Mobile Learning to support physical education learning (Yang et al., 2020). Although there is evidence of the negative impact of internet access, social media, and mobile device usage on contemporary education (Chu, 2014), the utilization of mobile technology continues to grow in the field of education (Sobral, 2020). The growth of mobile devices is clearly faster than the growth of the global population. According to the Cisco Annual Internet Report (2018–2023) published in March 2020, smartphones are expected to experience the second-fastest growth by the end of 2023 (Criollo-C et al., 2021).

With the rapid advancement of technology, the education system must adapt and implement these innovations

effectively across all academic fields (Bustillo et al., 2017). Therefore, the implementation of mobile learning-based education in learning activities will create a more natural and effective learning method for the current generation (Dingli & Seychell, 2015).

In the context of physical education, mobile learning offers various opportunities to enhance the quality of learning (Kim et al., 2017). This technology allows teachers and students to access learning materials, physical activity guides, and instructional videos that support the practical learning process (Zhu & Dragon, 2016). In addition, mobile learning can enhance student motivation through the integration of game-based applications (gamification) and real-time tracking of physical activities (Khaddage et al., 2016).

Previous studies have shown that the use of mobile learning can have a positive impact on the learning process and outcomes. For example, a study by Luong et al., (2021) found that the use of mobile-based applications in physical education significantly increased student participation

in physical activities. Another study by revealed that the integration of mobile learning in sports education provides a more interactive learning experience and encourages students to be more active in understanding sports concepts (Barker et al., 2015). However, despite these benefits, several barriers hinder teachers' use of technology, including time constraints (Palao et al., 2015), high costs (Orlando, 2014), teacher workload (Pyle & Esslinger, 2014), inadequate teacher competence (Law, 2008), limitations in device practicality and mobility (Palao et al., 2015), and teachers' resistance to change and technology adoption (Kretschmann, 2015).

Considering these challenges and opportunities, it is essential to explore how mobile learning can be optimally adapted in physical education. This study aims to identify the challenges and opportunities in implementing mobile learning and provide strategic recommendations to enhance learning effectiveness in the digital era.

Materials and methods

Study Participants

This study utilizes data sources from internationally published scientific articles registered in the Scopus database, which is recognized for its credibility.

The analyzed data consists of articles with an H-Index published in international journals and accessible through the Taylor & Francis Database, with a publication period between January 2019 and December 2024. Data collection in this study is divided into two categories: primary data sources and secondary data sources. Data coding in this study is conducted using a worksheet that serves a dual role as both an internal audit instrument and a tool for considering the exclusion of certain studies during the synthesis stage.

The article search in the Scopus database was conducted using two keywords: "Mobile Learning" and "Physical Education," with a publication timeframe from January 2019 to December 2024. The application of the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) standards is illustrated through a flow diagram (Figure 1) (Karo-Karo et al., 2023; Moher et al., 2016; Sari et al., 2024), which is applied in the stages of identification, screening, eligibility selection, and inclusion, resulting in a total of 10 articles analyzed from 241,924 articles.

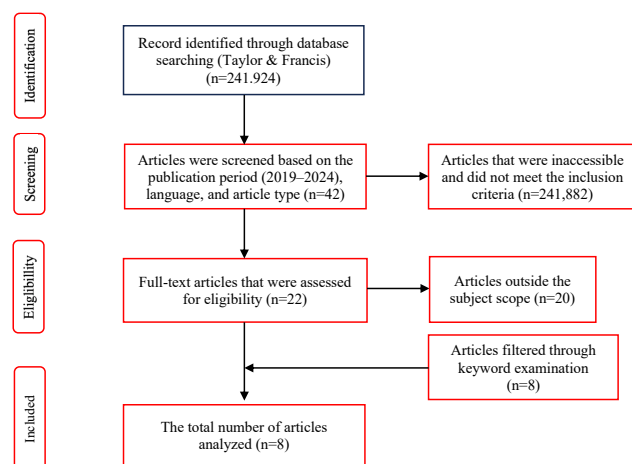


Fig. 1. Flow diagram of article selection

Bibliometric analysis involves various components, including the total number of authors, fields of study (such as mobile learning and physical education), types of research (such as experimental, descriptive, correlational, and others), annual publication trends from January 2019 to December 2024, distribution of publications based on the first author's institution, total number of authors, and the average number of citations per article.

Study Organization

The literature analysis covers six main aspects: publication trends during the period from January 2019 to December 2024, the institutions of the first authors, the composition of the number of authors, the focus of the study on Mobile Learning and Physical Education, the research methodologies (experimental, descriptive, correlational, and others) applied, as well as the average citation rate per article.

Statistical Analysis

The article titles, abstracts, and keywords were condensed to form a core set of publications that can be utilized and reviewed further. The review authors only included open-access articles in their study to ensure that everyone could access the research. The application of inclusion and exclusion criteria was carried out to select studies that specifically address one particular topic.

Results

Analysis of the 8 selected articles from a total of 241,924 articles using the PRISMA method revealed several key findings regarding the implementation of mobile learning in physical education. The results of this study highlight that the implementation of mobile learning in physical education faces various challenges while also offering significant opportunities.

Discussion

The results of this study indicate that the implementation of mobile learning in physical education faces various challenges, but also offers significant opportunities for enhancing the effectiveness of learning. The main challenges identified include the lack of teacher training in the use of technology, limited infrastructure, and the potential decrease in student physical activity due to the use of inappropriate apps. Additionally, the readiness of both teachers and students to adopt digital technology remains a challenge that needs attention. Resistance to technology in outdoor education environments is also a factor that can hinder the optimal implementation of mobile learning.

According to the study by Ng et al. (2021), one of the biggest barriers to the implementation of mobile learning is the lack of teacher competence in integrating technology into teaching methods. Teachers need to understand the Technological Pedagogical Content Knowledge (TPACK) approach to effectively integrate technology into physical education. In addition, research by Bonfield et al. (2020) shows that infrastructure limitations, such as access to devices and stable internet, pose significant challenges in

Table 1. Summary of the Research Table

No	Author and Years	Method	Main Result
1.	(Ng et al., 2021)	Quantitative	Challenges: Difficulties in technology use by teachers, limited student access to technology, and the adaptation of digital assessment methods. Opportunities: Mobile Learning can serve as a solution to enhance the effectiveness of distance learning, particularly for students with special needs, as highlighted in this study.
2.	(Bonfield et al., 2020)	Literature Review	Challenges: Technical and infrastructure barriers, including access to devices and stable internet. The readiness of teachers and students to adopt technology in movement-based learning. Opportunities: Mobile learning can enhance accessibility and flexibility in PJOK learning, especially in theoretical lessons. Additionally, AI and digital assistants can provide personalized feedback to students in physical exercises.
3.	(Goad et al., 2019)	Qualitative	The main challenge in online physical education is ensuring that students are genuinely participating in physical activities. This article mentions that traditional verification methods, such as activity logs, online discussions, and self-reports, are less accurate. Mobile learning may limit the interaction between students and instructors, which is a crucial element in physical education. Opportunities: Mobile learning allows students to access materials anytime and anywhere. This aligns with the concept of blended learning used in online physical education. Additionally, applications like Fitocracy, MyFitnessPal, and MapMyRun support activity-based learning with features for tracking exercises, performance analysis, and social interaction.
4.	(Iannucci et al., 2023)	Self-Study Research	Teachers recognize that the use of digital technology can help overcome assessment challenges in physical education. Digital technology allows teachers to access various assessment methods that are more accurate and flexible. However, teachers face obstacles such as limited technical support, time, and resources.
5.	(Isgren Karlsson et al., 2023)	Mixed-Methods	In outdoor education, digital technology allows students to access prior information, better preparing them for outdoor activities and documenting the learning process. However, a challenge faced is that some teachers feel digital technology disrupts students' experiences in natural environments. They believe that outdoor education should focus on direct interaction with nature without the distractions of technology.
6.	(Laughlin et al., 2019)	Qualitative	Video technology allows teachers to provide immediate feedback, monitor student skill development, and conduct evidence-based assessments. This presents an opportunity for more effective implementation of mobile learning. Challenges: Technical barriers (access to devices and applications); readiness of teachers and students to adopt technology.
7.	(Lee & Gao, 2020)	Qualitative	Challenges: Reduced physical engagement as some apps increase students' sedentary time, the selection of inappropriate apps that focus only on classroom management without making a significant contribution to physical activity, and difficulties for teachers in aligning the use of technology with learning objectives. This necessitates careful consideration in choosing apps that can truly enhance physical involvement and student motivation. Opportunities: Positive potential in using mobile technology for physical education, where selecting the right apps—such as those based on gamification or physical activity tracking—can enhance students' learning experiences. This is especially true when apps provide immediate feedback through features like movement analysis based on video, which has the potential to improve self-efficacy and students' understanding of various sports movements.
8.	(Klimova, 2019)	Quantitative	Challenges: Ensuring that the use of mobile learning continues to promote physical activity and does not inadvertently reduce students' movement. Opportunities: Mobile apps can be used to provide immediate feedback, monitor physical activity, and deliver theoretical content related to sports.

the implementation of mobile learning, especially in areas with limited resources.

On the other hand, mobile learning offers various opportunities that can support physical education learning. This

technology can enhance accessibility and flexibility in learning, allowing students to access materials anytime and anywhere. According to Goad et al. (2019), the implementation of gamification-based mobile apps can enhance student motiva-

tion and participation in physical activities. Apps like MyFitnessPal and MapMyRun have been proven to increase student engagement in monitoring their physical activity, thus contributing to the development of a healthy and active lifestyle.

The ability of mobile learning to provide evidence-based assessments and real-time feedback is also an advantage that can help students better understand sports movements. The study conducted by Iannucci et al. (2023) found that video-based technology allows students to review their movements and receive real-time feedback, which helps in the development of motor skills and understanding of sports concepts. This technology can also support personalized learning by allowing students to adjust the pace of their learning according to their own preferences.

In addition, the use of mobile learning in the blended learning model is increasingly growing in the field of education. According to research by Lee and Gao (2020), the combination of digital learning and face-to-face learning provides greater flexibility for both students and teachers in managing time and learning methods. With mobile learning, students can independently study sports theory through digital materials, while practical sessions are still conducted directly on the field.

The implementation of mobile learning can also help overcome time and resource limitations in physical education. According to Klimova (2019), digital technology allows teachers to automate several aspects of learning, such as assessments and tracking student progress, enabling them to focus more on direct interaction with students during physical activities. Thus, mobile learning not only enhances teaching efficiency but also helps optimize the student learning experience.

However, it is important to note that the success of implementing mobile learning in physical education greatly depends on the strategies employed. As revealed by Isgren Karlsson et al. (2023), some teachers still feel that the use of technology may disrupt students' direct experience with the natural environment in outdoor education. Therefore, there needs to be a balance between the use of technology and experiential learning to ensure that students can still reap the full benefits of both approaches.

Thus, despite the various challenges in implementing mobile learning, the benefits it offers demonstrate that this technology holds great potential in enhancing the effectiveness of physical education learning. Therefore, appropriate strategies are needed to address existing challenges, such as enhancing teacher training, developing technological infrastructure, and selecting applications that can truly support students' physical activities. With a well-planned approach, mobile learning can become an innovative solution in physical education in the digital era.

Conclusions

The implementation of mobile learning in physical education faces challenges such as infrastructure limitations, lack of teacher competence in technology, and the potential decrease in physical activity among students due to the use of inappropriate applications. However, this technology also offers significant opportunities to enhance accessibility, flexibility, and student engagement through gamification, physical activity tracking, and evidence-based assessment. Its successful implementation depends on the right strategies,

including teacher training, infrastructure improvement, and the selection of applications that support active learning. Thus, mobile learning can become an innovative solution in physical education in the digital era.

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Conflict of Interest

All the authors have no conflicts of interest to declare.

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Визначення викликів та можливостей у впровадженні мобільного навчання на заняттях з фізичного виховання: Огляд літератури

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 6 с., 1 табл., 1 рис., 27 джерел.

Мета дослідження. Це дослідження мало на меті визначити виклики та можливості щодо впровадження мобільного навчання у фізичному вихованні, акцентуючи увагу на його впливі з точки зору ефективності навчання, залученості студентів та підготовленості викладачів.

Матеріали та методи. У цьому дослідженні проведено систематичний огляд статей, індексованих наукометричною базою даних Scopus (2019-2024 рр.), у яких розглянуто питання застосування мобільного навчання у фізичному вихованні. Дослідження проводилось згідно з методологією PRISMA, шляхом відбору 10 релевантних статей з початкового набору

даних у кількості 241,924. Аналіз охоплював тенденції публікацій, фокус досліджень, методології та частоту цитування з метою оцінювання ролі мобільного навчання у фізичному вихованні.

Результати. Отримані дані вказують на наявність як викликів, так і можливостей щодо застосування мобільного навчання у фізичному вихованні. Основні проблеми включають обмежену технологічну інфраструктуру, недостатню підготовку викладачів та потенційне зниження фізичної активності студентів через неналежне використання додатків. Однак використання технології мобільного навчання пропонує значні переваги, як-от підвищена доступність, гнучкі варіанти навчання, гейміфікація з метою мотивації та відстеження успішності в реальному часі. Ефективне впровадження зазначеної технології навчання потребує відповідної підготовки викладачів, покращеної інфраструктури та ретельного відбору цифрових інструментів, які сприятимуть залученню студентів до занять фізичною активністю.

Висновки. Мобільне навчання має потенціал для поліпшення навчального процесу з фізичного виховання за умови його стратегічної інтеграції. Подолання технологічних та педагогічних бар'єрів може максимізувати його переваги, сприяючи більш інтерактивному та ефективному навчанню.

Ключові слова: виклики, можливості, мобільне навчання, фізичне виховання, огляд літератури.

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Using a Reflective Research Approach on the Implementation of Teaching Games for Understanding in Physical Education: A Scoping Review

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Abstract

Background. Teaching games for understanding (TGFU) learning is an innovative model to improve motivation, participation, and motor skills. In the implementation, special analyses are needed to determine future opportunities.

Objectives. This study aimed to conduct a scoping review of the implementation of TGFU.

Materials and methods. This literature review used a scoping method to collect data through Google Scholar, Pubmed, Wiley, and Scopus databases. The data inclusion criteria were original quantitative and mixed articles discussing TGFU, research focusing on the implementation of TGFU, research written in English, and published between 2020 and 2025. Furthermore, data screening identified 20 final articles using quantitative and qualitative methods through Rayyan and Mendeley.

Results. According to study's results, the highest number of published articles was 5 (25%) and 4 (20%) in 2018 and 2024, respectively. The results were categorized into four key themes, namely (1) Implementation – primarily focused on improving game understanding and decision-making, (2) Challenges and Obstacles – difficulties in modifying learning, curriculum adjustments, time constraints, and variations in students' engagement, (3) Effectiveness – increased participation, motivation, and motor skill development, and (4) Success Factors – influenced by adequate training, students' participation, curriculum balance, environmental support, evaluation, and the types of modified games used.

Conclusions. The findings of this study show that continuous training for teachers and curriculum adjustments were needed to implement TGFU effectively.

Keywords: teaching games for understanding (TGFU), physical education, scoping review.

Introduction

Physical education is important in optimizing physical, character, and social skills. However, sports learning is trapped in conventional methods focusing on individuals without providing a comprehensive understanding of important aspects such as strategy and decision-making (Rokhayati et al., 2016; Yahya, Amry & Sufitrono, 2020). Active participation, motivation, and interest in physical education need to be improved by learning methods containing games. This is achieved by using the teaching

games for understanding (TGFU) learning. The process focuses on contextual understanding in games as part of sports skills learning (Arantes et al., 2025; Lodewyk & Robertson, 2022; Oktavianus et al., 2025). TGFU was first proposed by Bunker & Thorpe, which provides great potential to improve understanding of various aspects of strategy and motivation (Barquero-Ruiz et al., 2024). This includes cognitive skills and tactical decisions in games (Barquero-Ruiz et al., 2024; Lodewyk, 2022).

The implementation of TGFU requires special attention, even though the method is effective. In Indonesia, some schools are more focused on remote areas and facing problems in implementing TGFU learning. This is evident in the shortage of qualified teacher training and the limitations of facilities and infrastructure (Gandasari et al., 2024; Ibra-

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him et al., 2021). TGFU offers a holistic method for learning about physical education. Therefore, some teachers do not fully understand the integration with more effective goals. The effect increases active participation and students' interest but there are challenges in the implementation process, leading to the inability to obtain optimal results. Based on the description, a scoping review should be conducted to understand the context and broad scope of TGFU implementation. This differs from a systematic review focusing on evaluating and answering specific questions to determine the effectiveness or effect of a particular theory (Hafidz et al., 2024). Additionally, a scoping review aims to map broader literature and provide an overview of a particular topic (Deehan et al., 2024; Munn et al., 2018). The method is very important in identifying various research relevant to TGFU and mapping the application in multiple contexts (Samdin et al., 2021). This literature review used a scoping method to direct future investigations. For example, research on the effectiveness of TGFU has been relatively conducted, including Samdin et al. and Gustian et al. (Gustian et al., 2024a; Samdin et al., 2021). However, there are still some unanswered questions, such as the effect of TGFU on the level of students' engagement with different educational backgrounds. Based on the result, this research serves as a clearer guideline on the effect of external factors, namely the availability of facilities, on the implementation of TGFU (Pratama et al., 2023; Vernanda, 2023).

A clear map is provided for future investigation focused on implementing TGFU. The increasing number of research provides a strong background for reforming physical education and implementing more effective methods. Therefore, this research aims to explore secondary data focused on the implementation of TGFU in physical education with a scoping review method. The research questions include (1) how is the implementation of TGFU in physical education? (2) what are the challenges and obstacles faced in the implementation of TGFU in physical education? (3) how effective is the implementation of TGFU in increasing participation of students? (4) what are the factors affecting the success of TGFU implementation in the context of physical education?

Materials and methods

Research Design

The research type was a scoping review, which investigated the concept of literature systematically to synthesize useful results for further actions (Munn et al., 2018). The guidelines used were the Preferred Reporting Items for Systematic Reviews and Meta-Analysis for Review of Reviews (PRISMA-ScR) (Trandafirescu et al., 2024). This method identified gaps and analyzed evidence on the research topic (Trandafirescu et al., 2024).

Research Eligibility

Data eligibility is determined using inclusion and exclusion criteria described as follows.

Inclusion Criteria

- Type of research - Primary articles in the form of quantitative and systematic reviews that discuss the

implementation of TGFU in physical education. The databases used are Google Scholar, Scopus, Pubmed, and Willey.

- Subject and context - Research that focuses on the implementation of TGFU in the context of physical education, analyses conducted at various levels of primary and secondary education, complete downloadable article text.
- Language - The language included in the inclusion criteria is English.
- Year of publication: Articles published in the last 5 years from 2020-2025.
- Research focus - Research discussing the implementation of TGFU in the context of physical education learning.

Exclusion Criteria

- Type of research - Research irrelevant to the topic discussing the basic theory of TGFU without implementation, opinion articles and conferences that do not present empirical data, and analyses examining other topics in physical education without connecting to TGFU.
- Subject and context - Research that does not focus on physical education for athletes and professional sports, analyses discussing non-education in sports, and article text that cannot be downloaded
- Language: Articles not published in English.
- Year of publication: Articles published more than 5 years.
- Focus of research: Research that discusses theory irrelevant to TGFU, and analyses examining the concept without including application in physical education.

Search Strategy

This research is presented in the following procedures through a systematic data search strategy:

1. Observational research and document analysis in the form of the latest relevant articles to determine the urgency.
2. Conducting exploration of research questions to focus the discussion.
3. Data search in the form of articles in Google Scholar, Pubmed, Scopus, and Willey databases by applying Boolean words, namely:
 - "Teaching games for understanding" AND "Implementation" AND "physical education". Focusing on tracing articles that discuss TGFU in the context of implementation in physical and physical education.
 - "TGFU" AND "Challenges" AND "Effect" AND "Skills" OR "Understanding" AND "Physical Education". Focusing on finding literature that discusses the effect of TGFU on the skills and understanding of students in physical education.
 - "TGFU" AND "effectiveness" AND "motivation" AND "physical education". Focusing on finding effectiveness in motivation.
4. A total of 144, 3, 39, and 4 data are retrieved from Google Scholar, Pubmed, Scopus, and Willey.

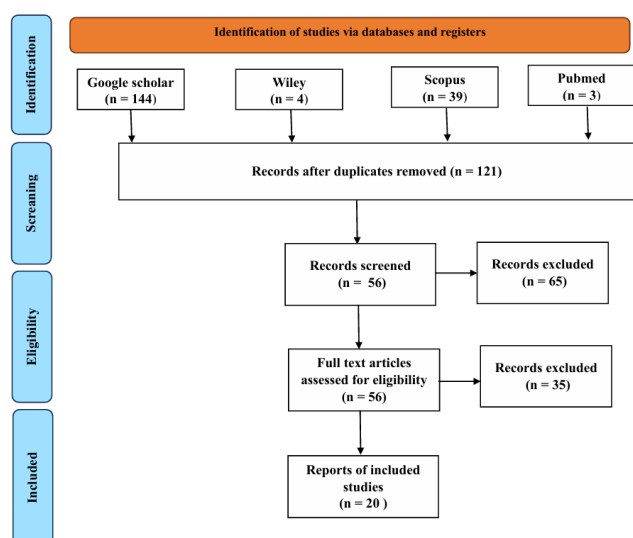


Fig. 1. The research flow diagram based on PRISMA-ScR

5. The data reported were screened to find duplicate and relevant articles. The initial screening obtained 121 data and the subsequent stage was filtered to obtain 56 data.
6. In the final analysis, 20 articles were declared eligible to be presented more clearly with PRISMA-ScR analysis as follows:

Data Synthesis

Data filtering starts with searching for articles in Scopus, Google Scholar, Willey, and Pubmed databases obtained with files in RIS format. The data is uploaded to the “Rayyan” device to filter duplicates, completeness of abstracts, and relevance of articles. Subsequently, the filtering results

are entered into Mendeley application as final data and synthesized with a structured method to obtain a systematic synthesis (Yudhistira et al., 2023).

Results

The synthesis of results aims to present data that meets the criteria of this research. The initial filtering stage identifies and removes duplicate articles ($n = 121$), reducing the dataset to ($n = 56$). An additional ($n = 65$) articles are excluded, followed by a second filtering process based on inclusion and exclusion criteria, resulting in the removal of ($n = 35$). Therefore, the final data was found ($n=20$) and the summary is presented in Tables 1, 2.

Table 1. Total publications per year that meet the inclusion criteria

Year	Total	Percentage
2018	5	25 %
2019	2	10 %
2020	3	15 %
2021	2	10 %
2022	1	5 %
2023	3	15 %
2024	4	20 %
2025	0	0 %
Total	20	100%

Based on the review analysis, 20 articles were reported as the final data. The overall analysis results explained the implementation of TGFU, the comparison of the methods, and the quantitative method of the original research in elementary and secondary schools (Arias-Estero et al., 2020; Batez et al., 2021; García-González et al., 2020; Ginciene et al., 2023; Waffak, Sukoco, Sugiyanto, et al., 2022; Wang & Wang, 2018).

Table 2. Data description based on PRISMA-ScR analysis

No	Reference	Participant	Method	Results
1	(García-González et al., 2020)	14 senior high school students with an average age of 15 years. The sample size was 49.	Experimental pretest-posttest without control	The results reported that the implementation of TGFU learning had a positive effect on motivation of students.
2	(Morales-Belando et al., 2018)	23 males and 18 females. Total sample 41	Pretest-posttest experiment without control	The results showed that after implementing TGFU soccer learning, students experienced an increase in compliance and performance.
3	(Lodewyk & Bracco, 2018)	25 female senior high school students	Survey research	TGFU increased self-confidence, and reduced anxiety from conventional physical education methods.
4	(Wang & Wang, 2018)	118 students from four classes were divided into TGFU and engineering groups.	Factorial experiment	- TGFU and engineering groups performed equally well. - TGFU group spent more time in moderate to vigorous activity than the engineering group. - Boys spent more time in moderate to vigorous activity than girls. - There was no significant difference between high and low-skill groups.

Table 2 (continued)

No	Reference	Participant	Method	Results
5	(Qohhar, 2018)	80 senior high school students	Experimental nonequivalent group pretest-posttest design	- There was a significant effect of Times Game Tournament (TGT) model on basic football skills. - There was a significant effect of TGFU learning model on basic football skills. - There was a significant difference between TGT and TGFU. TGT model was better for improving basic football skills.
6	(Fani & Sukoco, 2019)	31 senior high school students for a small-scale test. 62 students for a large-scale test.	Development research	The small and large-scale test phases of TGFU learning method were good and very good, respectively.
7	(Calábria-Lopes, 2019)	18 beginner basketball students	One group pretest-posttest design experiment	- There was no correlation between product and process performance for basketball skills. - There were significant differences between the pretest and posttest for the passing process, shooting performance in the game context, and knowledge of skills. - There were no differences between isolated shooting and passing skill assessments.
8	(Harvey, Gil-Arias, et al., 2020)	12 elementary school students	Pretest posttest design experiment	The research results showed an increase in students' abilities to evaluate game situations and develop tactical reasoning.
9	(Arias-Estero et al., 2020)	12 elementary school students	Quantitative and qualitative mix	- There was no difference between the first and second tests. However, there was a significant increase after both periods compared to the first assessment. - Qualitative support implemented by the pedagogical strategies explained the similarities between the first and second periods.
10	(Nopembri et al., 2022)	32 senior high school students.	Classroom action research	The learning process with TGFU improved HOTS skills.
11	(Batez et al., 2021)	54 junior high school students	Quasi-experiment	The short duration of TGFU learning model in the context of volleyball learning improved skills.
12	(Santoso et al., 2021)	46 elementary school students	Quasi-experiment	The results found that PBL and TGFU had a positive effect on soccer playing skills.
13	(Waffak, Sukoco, & Sugiyanto, 2022)	165 respondents	Quantitative approach to testing content and construct validity	The structured model could increase HOTS, reduce bullying, and affect students' cognitive, affective, and psychomotor skills, hence, the structured model was safe and made students more enthusiastic.
14	(Ginciene et al., 2023)	12 elementary school students	Action research	The results showed changes in pedagogical practices aimed at helping players understand and use actions to support futsal improvement.
15	(Papagiannopoulos et al., 2023)	6 elementary school students	Quantitative and qualitative	The results reported that students had positive views of TGFU learning model and were generally satisfied with the effect on development.
16	(Okasha & Muszali, 2023)	60 elementary school students	Quasi-experimental design	There were statistically significant differences between the two groups in terms of positive behavior, understanding of rules and strategies, and enjoyment of physical education, as measured by the total post-test score.

Table 2 (continued)

No	Reference	Participant	Method	Results
17	(Romadhona et al., 2024)	68 senior high school students	Quasi-experimental design	The results reported that TGFU allowed students to be active in extending overall learning time.
18	(Li & Chano, 2024)	60 students were randomly selected from a total of 1850 students.	- Traditional teaching methods - Experimental classes taught using TGFU learning method.	- Remarkable improvements were seen in basketball technical level (skill level, game performance) after TGFU learning. - Significant improvements were also reported in physical fitness after TGFU learning. - TGFU-based teaching mode improved basketball tactics, including three-point shooting, dribbling drive, and game performance. Therefore, the mode was beneficial to cultivating technical, tactical, and athletic abilities.
19	(Pizarro et al., 2024)	11 roller skaters, and roller hockey players from the under 10 category from school clubs.	Intra-group, quasi-experimental design	- An increase was reported in some forms of autonomous motivation and a decrease in controlled motivation, as hypothesized. - The results could be explained by considering the focus of TGFU learning on the conceptual, cognitive, and tactical aspects of sports as well as the Ludotechnical Model on the provision of enjoyable experiences.
20	(Gustian et al., 2024).	24 fourth-grade elementary school students from two classes	Pre-expressive with One Group Pretest Posttest design type	- At the time of the pretest, the motor mixture of students was in the average and poor categories. Therefore, improving the motor skills was very necessary. - The posttest showed that there was an increase in the category of abilities since no student was at below-average levels.

Discussion

SQ1: How is the implementation of TGFU in physical education?

The implementation of TGFU learning starts with the use of modified games according to the skill level of students. In Chinese research conducted on learning basketball, the game was modified to teach students tactical play. This allowed for the development of a deeper understanding of rules and strategies in the context of the game. The model enabled students to be actively included in learning about in-depth aspects (Li & Chano, 2024). Furthermore, the implementation of TGFU in physical education with the introduction of games permitted direct participation while learning about the tactical aspects. This provides students with the opportunity to understand and master students' skills separately (Arias-Estero et al., 2020; Fani & Sukoco, 2019; Morales-Belando et al., 2018).

Tactical understanding through decision-making is the core of TGFU implementation in the game. Students are allowed to reflect on decisions made during the game to understand the importance in the larger context. The teaching of basketball with TGFU learning model shows an increase in understanding of game strategy. This leads to greater engagement and more opportunities to apply skills in real situations (Morales-Belando et al., 2018). Furthermore, students are helped in making connections between skills and the application in the context of the game (Morales-Belando et al., 2018).

Previous research reported active participation and motivation of students. In this context, students who follow

basketball learning with TGFU show increased intrinsic motivation and participate more in physical activities (Gustian, Gandasari, et al., 2024; Okasha & Muszali, 2023). In soccer games, students learn to dribble, kick, and pass as well as apply tactical decision-making (Fani & Sukoco, 2019; Wang & Wang, 2018). In the application of TGFU, small games and modified teams reduce students' waiting time, ensuring more physical activity with the potential to increase students' active participation (Romadhona et al., 2024; Wang & Wang, 2018).

TGFU learning is about social and cooperation aspects. In the implementation of basketball games, TGFU increases cooperation between students and strengthens the understanding of the game (Okasha & Muszali R 2023). Therefore, TGFU develops physical, social (Okasha & Muszali, 2023), and motor skills of students (Gustian et al., 2024). TGFU focuses on outcomes and the decision-making process of students through process and outcome evaluation. Evaluation is carried out to measure changes in tactical understanding, skills, active involvement, motivation, and satisfaction (Morales-Belando et al., 2018). Therefore, the implementation of TGFU learning aims to improve game understanding, decision-making, and skills through physical activity.

SQ2: What are the challenges and obstacles faced in the implementation of TGFU in physical education?

Difficulty in implementing learning by teachers is a fundamental problem. This model is quite complex, requiring sufficient skills and time to manage the class differently

from the usual conventional methods. Furthermore, some teachers feel hesitant to apply TGFU learning to students. In line with other research, the model has the potential to improve students' understanding, but there are still teachers experiencing difficulty (Papagiannopoulos et al., 2023). Switching to a model focused more on understanding the game and decision-making may be complex due to the absence of clear implementation guidelines. Therefore, there should be a clear TGFU guideline on the application of the model in the context of physical education to address problems of implementation (Calábria-Lopes et al., 2018). Teachers cannot translate from theory to practice without a clear guideline (Wang & Wang, 2018).

A further challenge is the suitability of the existing curriculum. The previous curriculum focuses on technical teaching before the game, while TGFU learning requires a method of tactical understanding. This causes discomfort for teachers who feel compelled to change teaching methods (Nopembri et al., 2022; Santoso et al., 2024). Additionally, classic problems such as limited teaching time have been obstacles for a long time. TGFU is effective but the method is limited by time and suboptimal learning (Arias-Estero et al., 2020; Harvey, Gil-Arias, et al., 2020). For example, this method requires sufficient time for students to understand and apply the principles of the game (Gustian et al., 2024; Malim, 2023).

Other obstacles include the uneven skills of students and the varying levels of active participation during learning. Heterogeneous groups are a challenge to maintain active participation for students and these are characterized by inequality in the skills of students (Ginciene et al., 2023; Wang & Wang, 2018). TGFU model requires all students to participate in the game, but individuals with lower skills may feel left behind (Lodewyk & Bracco, 2018; Papagiannopoulos et al., 2023). The biggest challenge in implementing TGFU is often the lack of socialization (Romadhona et al., 2024). Therefore, teachers who are not well-trained cannot use the full potential of the method, reducing the success of improving the skills of students (Harvey, Gil-Arias, et al., 2020; Romadhona et al., 2024). This leads to inconsistent implementation, specifically when there is no clear balance between theory and practice (Harvey, Gil-arias, et al., 2020). The inconsistency is from the lack of a common understanding between teachers and students (Calábria-Lopes et al., 2018). Another consequence is the difference in perception about the effectiveness of TGFU. Some teachers are skeptical about the effectiveness due to a lack of in-depth understanding of TGFU concept (Santoso et al., 2024).

TGFU offers a holistic method but faces various challenges such as difficulties in implementing learning modification, curriculum adjustment, time constraints, and differences in active participation. There must be intensive training and socialization, clear guidelines, as well as the preparation of time, and strategies to overcome obstacles.

SQ3: How effective is the implementation of TGFU in improving students' motivation, participation, and motor skills in physical education?

TGFU has a positive effect on learning motivation. In TGFU-based classes, students show intrinsic motivation and active participation in learning. The intrinsic motivation category reflects personal drive in the activity (Fani &

Sukoco, 2019; Romadhona et al., 2024). This motivation can be seen from the comfort and interest in learning (Fani & Sukoco, 2019; Qohhar, 2018). In line with other research, students taught with TGFU model show higher levels of internal motivation, and there is a decrease in external regulation (García-González et al., 2020; Li & Chano, 2024).

According to the result, motivation is related to active participation. This is because TGFU learning model promotes active participation and increases academic learning time in the experimental group (Wang & Wang, 2018). In addition, TGFU structure focused on game-based learning allows participation (Romadhona et al., 2024). In modified games, students participate in problem-solving and decision-making to reduce the tendency to wait passively, which often occurs in traditional learning models (Gustian et al., 2024; Papagiannopoulos et al., 2023).

An equally important goal of physical education is the enhancement of motor skills. TGFU learning media can be used to improve the motor skills of elementary and middle school students (Ginciene et al., 2023). These abilities can be improved by integrating skills into the context of the game rather than focusing on the methods (Morales-Belando et al., 2018). Learning using modified games allows students to make better decisions in the context of real games. For example, the model improves volleyball skills in terms of passing and participating in the game (Batez et al., 2021; Gustian et al., 2024).

Based on the description above, the implementation of TGFU in physical education is effective in increasing participation and motivation as well as improving motor skills through a learning process. This model enables students to enjoy learning, and apply skills in real-game scenarios, significantly improving cognitive and physical development.

SQ4: What are the factors affecting the success of TGFU implementation in the context of physical education?

The readiness and training of teachers affect the success of TGFU learning implementation. Teachers trained to implement learning tend to develop effective plans, manage classes, and provide constructive feedback. The skills required to modify games play an important role in the effectiveness of TGFU learning model (Li & Chano, 2024; Okasha & Muszali, 2023). Furthermore, tactical understanding is the main factor influencing TGFU implementation. Teaching games with a core understanding of strategies, concepts, and decision-making are more effective than focusing on basic methods. Understanding tactics can develop motor and cognitive skills holistically (Batez et al., 2021). This is related to the active participation of students in learning process. TGFU learning model emphasizes inclusion in learning through modified games. Students explore games to solve tactical problems and make quick decisions in developing a sense of autonomy (Okasha & Muszali, 2023). This can also affect the level of active participation during learning (Gustian et al., 2024).

Based on the result, the suitability of the curriculum objectives and school context is a problem. Schools with a curriculum supporting game-based learning support the implementation of games with various modifications to implement TGFU. Subsequently, adjustments to the needs and abilities of students are very important (Gustian et al., 2024). The implementation of TGFU is successful when school management supports and gives teachers the

freedom to innovate with intense discussion and training (Papagiannopoulos et al., 2023). The experience of teachers who have implemented TGFU is a valuable reference to motivate and help other teachers (Nopembri et al., 2022).

The success of TGFU should be able to modify the game according to the learning objectives. Games modified to suit the skill level of students and have clear tactical objectives are more effective in developing cognitive and motor skills (Batez et al., 2021; Gustian et al., 2024). In addition, the learning model can be adjusted according to class dynamics, students' understanding levels, and desired outcomes through continuous evaluation (Gustian et al., 2024a; Li & Chano, 2024). The implementation of TGFU is affected by a combination of adequate training, participation in learning, curriculum suitability, environmental support, and evaluation, as well as the type of modified game adjustment. These factors create an engaging, effective learning environment to develop skills and tactical understanding in physical education.

Conclusions

In conclusion, TGFU learning model was effective in physical education and focused on tactical understanding and decision-making. This learning model increased students' engagement, motivation, and motor skills during active learning. However, the implementation faced challenges such as a lack of teacher training and limited facilities in some remote areas, as well as incompatibility with the traditional curriculum. Furthermore, evaluation in TGFU measured the process and participation of students in decision-making. Based on the results, this research recommended ongoing training for teachers and making curriculum adjustments for the effective implementation of TGFU. The success of the model was affected by external factors such as school facilities and education policies.

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Conflict of interest

All the authors have no conflicts of interest to declare.

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Використання рефлексивного дослідницького підходу щодо впровадження методики навчальних ігор для тренування розуміння у фізичному вихованні: Огляд предметного поля

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 14 с., 1 таб., 1 рис., 40 джерел.

Історія питання. Навчальні ігри для тренування розуміння (Teaching games for understanding, TGFU) — це інноваційна модель навчання, спрямована на покращення мотивації, залученості до процесу та рухових навичок. На етапі впровадження моделі необхідно провести спеціальні аналітичні дослідження, щоб визначити подальші перспективи.

Мета дослідження. Мета цього дослідження полягала у проведенні огляду предметного поля щодо впровадження методики TGFU.

Матеріали та методи. У цьому огляді літератури застосовано метод предметного поля для збору даних із використанням наукометричних баз даних Google Scholar, Pubmed, Wiley та Scopus. До критеріїв включення даних були віднесені оригінальні кількісні та змішані статті, в яких розглядалися питання TGFU, дослідження щодо впровадження TGFU, дослідження англійською мовою, опубліковані в період з 2020 по 2025 рік. Крім того, в результаті скринінгу даних було відібрано 20 остаточних статей із використанням кількісних та якісних методів за допомогою програмного забезпечення Rayyan та Mendeley.

Результати. Згідно з результатами дослідження встановлено, що найбільша кількість опублікованих статей становила 5 (25 %) та 4 (20 %) у 2018 та 2024 роках відповідно. Результати були класифіковані за чотирма ключовими тематиками, а саме: (1) Впровадження — передусім зосереджено увагу на поліпшенні розуміння гри та процесу ухвалення рішень, (2) Виклики та перешкоди — труднощі у модифікації навчального процесу, коригування навчальних програм, часові обмеження та варіації залучення учнів, (3) Ефективність — підвищена залученість, мотивація та розвиток рухових навичок, і (4) Фактори успіху — визначаються належною підготовкою, залученістю учнів, збалансованістю навчальних програм, сприятливістю зовнішнього середовища, оцінюванням, а також типами використовуваних модифікованих ігор.

Висновки. Результати цього дослідження показують, що для ефективного впровадження методики TGFU необхідно забезпечити організацію безперервного навчання для викладачів та скоригувати навчальні програми.

Ключові слова: навчальні ігри для тренування розуміння (TGFU), фізичне виховання, огляд предметного поля.

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Retraction Note

Retraction Note: Engaging in Short-Term Moderate-Intensity Exercise Increases Growth Hormone Levels in Individuals with Obesity (Physical Education Theory and Methodology, 24(4), 619–625. <https://doi.org/10.17309/tmfv.2024.4.14>)

The Editors have retracted the following article:

Muhammad, Siantoro, G., Subagio, I., Yosika, G. F., Phanpheng, Y., Pramono, B. A., Kusuma, I. D. M. A. W., & Pranoto, A. (2024). Engaging in Short-Term Moderate-Intensity Exercise Increases Growth Hormone Levels in Individuals with Obesity. *Physical Education Theory and Methodology*, 24(4), 619–625. <https://doi.org/10.17309/tmfv.2024.4.14>

The Editors retract this article due to identified errors in citation. The authors did not consent to the retraction of the article. We have been informed in our decision-making by our policy on publishing ethics and COPE guidelines.

The retracted article will remain online to maintain the scholarly record, but it will be digitally watermarked on each page as “Retracted”.

References

Muhammad, Siantoro, G., Subagio, I., Yosika, G. F., Phanpheng, Y., Pramono, B. A., Kusuma, I. D. M. A. W., & Pranoto, A. (2024). Engaging in Short-Term Moderate-Intensity Exercise Increases Growth Hormone Levels in Individuals with Obesity. *Physical Education Theory and Methodology*, 24(4), 619–625. <https://doi.org/10.17309/tmfv.2024.4.14>

Повідомлення про відкликання

Повідомлення про відкликання: Заняття короткотривалими фізичними вправами помірної інтенсивності підвищують рівень гормону росту в осіб з ожирінням (Теорія та методика фізичного виховання, 24(4), 619–625. <https://doi.org/10.17309/tmfv.2024.4.14>)

Редакція відкликала таку статтю:

Мухаммад, Сіанторо, Г., Субагіо, І., Йосіка, Г. Ф., Пханпхен, Я., Прамоно, Б. А., Кусума, І. Д. М. А. В., & Праното, А. (2024). Заняття короткотривалими фізичними вправами помірної інтенсивності підвищують рівень гормону росту в осіб з ожирінням. *Теорія та методика фізичного виховання*, 24(4), 619–625. <https://doi.org/10.17309/tmfv.2024.4.14>

Редакція відкликає цю статтю через виявлені помилки в цитуванні. Автори не дали згоди на відкликання статті.

Під час прийняття рішень ми керувалися нашою політикою щодо етики публікацій та рекомендаціями COPE.

Відкликана стаття залишиться онлайн для збереження наукового запису, але на кожній сторінці буде цифровий водяний знак «Відкликано».

Посилання

Muhammad, Siantoro, G., Subagio, I., Yosika, G. F., Phanpheng, Y., Pramono, B. A., Kusuma, I. D. M. A. W., & Pranoto, A. (2024). Engaging in Short-Term Moderate-Intensity Exercise Increases Growth Hormone Levels in Individuals with Obesity. *Physical Education Theory and Methodology*, 24(4), 619–625. <https://doi.org/10.17309/tmfv.2024.4.14>

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Preliminary consideration of the submission (up to 3 weeks)

- appointment of an editor;
- checking the manuscript for consistency with the thematic scope of the journal;
- technical check (volume of the manuscript, volume of the abstract, assessment of the submission in terms of the stylistic and bibliographic requirements set forth in the Guidelines for authors);
- determining the relevance, novelty and originality of the paper;
- verifying the presence of a pedagogical experiment, its compliance with the research methods which can be repeated (representativeness of the sample, homogeneity of the sample in terms of age, motor fitness, level of sports fitness, training experience, etc.);
- if the manuscript is a review paper, the use of the PRISMA protocol, which covers systematic reviews and meta-analyses, is checked. Authors are recommended to complete the checklist and the flow diagram and include them in the submission;
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- literary editing;
- desktop publishing;
- familiarization of the authors with the layout;
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- preparation and upload of the electronic version of the journal.

Publication (on schedule)

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