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Фундаментальні рухові навички дітей, соціально-емоційний розвиток та розвиток фізичної активності на основі інтервенції з дитячої легкої атлетики: Метод моделювання структурними рівняннями (SEM) та аналіз..... 382-390

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Оче Віріаван, Андрі Суєко, Дані Приманата, Бекір Ерхан Орхан

Визначення показників максимальної сили м'язів, м'язової маси, пошкодження м'язів у активних дорослих чоловіків після проведення силових тренувань із низьким навантаженням та великою кількістю повторень у поєднанні із високим навантаженням та малою кількістю повторень 391-397

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Лайлі Міта Андріана, Реймонд Івано Аванді, Шеррі Айріс Заліллах, Єва Фердіта Юхант

З'ясування ефективності поєднання силових та аеробних вправ щодо покращення композиції тіла у жінок з ожирінням: Рандомізоване контрольоване дослідження..... 398-406

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Long-term Endurance Training as a Modulator for Preventing Cardiovascular Disease Risk in Obese Individuals

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Abstract

Objectives. This study aimed to evaluate the long-term effects of endurance training as a modulator in the prevention of cardiovascular disease risk in obese individuals.

Materials and methods. This study used a true experimental method with a pretest-posttest control group design. Twenty-five obese women aged 20-30 years with a body fat percentage of $\geq 30\%$ were assigned to a control group (CNT) and an exercise group (EXC). The EXC group underwent an eight-week (three sessions per week) endurance training program (treadmill) lasting 40-60 minutes per session. Blood pressure (BP), mean arterial pressure (MAP), and resting heart rate (RHR) were measured using an OMRON HBP-9030 digital tensiometer and a Polar H10 heart rate sensor at the start (pre) and after eight weeks (post) of endurance training.

Results. Significant reductions in systolic blood pressure (SBP), diastolic blood pressure (DBP), MAP, and RHR were detected between the pre- and post-endurance training phases (all $p \leq 0.001$). Additionally, a notable decrease in SBP, DBP, MAP, and RHR was observed between the groups (all $p \leq 0.05$).

Conclusions. The findings indicate the effectiveness of an eight-week endurance training intervention, contributing to a consistent reduction in SBP, DBP, MAP, and RHR in obese women.

Keywords: blood pressure, cardiovascular disease, obesity, physical exercise.

Introduction

Obesity is a significant global health issue, with prevalence rates continually rising in many countries (McKenzie et al., 2024). This condition is not only associated with metabolic disorders like type 2 diabetes but is also a major risk factor for various chronic diseases, including cardiovascular disease (CVD) (Rahmawati et al., 2024). Cardiovascular disease is one of the primary causes of morbidity and mortality among obese populations (Khafagy & Dash, 2021). Obese individuals tend to have higher systolic blood pressure (SBP) and diastolic blood pressure (DBP), as well as elevated resting heart rates (RHR) (Mathews et al., 2022; Palatini, 2021). These elevated parameters are directly linked to increased

risks of hypertension, coronary heart disease, stroke, and other cardiovascular complications (Jiang et al., 2024; Choi et al., 2024).

Physiologically, obesity is often associated with endothelial dysfunction, high peripheral vascular resistance, and increased sympathetic nervous system activity (Kajikawa & Higashi, 2022; Clayton et al., 2023; Agabiti-Rosei et al., 2024). Excess adipose tissue, particularly visceral fat, triggers low-grade chronic inflammation and oxidative stress, worsening vascular function and impairing blood pressure regulation (Kawai et al., 2021). Sympathetic nervous system hyperactivity in obese individuals also contributes to elevated blood pressure through vasoconstriction, increasing vascular resistance (Tanaka, 2020; Parvanova et al., 2023). Additionally, an elevated RHR in obese populations indicates a higher cardiac workload, which, over time, may lead to cardiovascular dysfunction (Palatini et al., 2021). Therefore,

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there is an urgent need for effective interventions to reduce blood pressure and RHR and lower cardiovascular risk in obese populations (Hannan et al., 2022).

Physical exercise is a well-recognized non-pharmacological approach to improving cardiovascular health (Weaver et al., 2022). Endurance exercise is one of the most recommended forms of exercise due to its broad benefits on the cardiovascular system (Milani et al., 2024). Endurance activities, such as running, cycling, or swimming at moderate intensity, have been shown to reduce blood pressure and RHR, enhance cardiac function, and improve aerobic capacity (Kishor Keshari et al., 2023). The mechanisms behind these benefits include increased vascular elasticity, reduced vascular resistance, and enhanced stroke volume—all factors contributing to improved cardiovascular function (Totoń-Żurańska et al., 2024). Additionally, endurance exercise can reduce sympathetic nervous system activity, promoting vasodilation and lowering blood pressure (Königstein et al., 2023; Zhang et al., 2024; Baffour-Awuah et al., 2024; Cornelissen & Fagard, 2005). In obese populations, who often have impaired cardiovascular function, the benefits of endurance exercise may be particularly significant and relevant (Koskinas et al., 2024).

Although numerous studies have evaluated the effects of endurance training on the general population and athletes, there is still limited understanding of its impact on obese individuals, particularly in short-term training programs (Bauer et al., 2021; Said Ouamer et al., 2020; Jabbarzadeh Ganjeh, et al., 2024; Kajikawa & Higashi, 2024). Most existing studies have focused on long-term training, while the effects of shorter, more practical training programs that are easier to implement on a broad scale remain underexplored (Bora et al., 2024). If structured endurance training proves effective in a shorter timeframe, it could become a realistic and easily implemented intervention for obese individuals to incorporate into their daily routines. Therefore, it is important to investigate whether endurance training over several weeks can have a significant positive impact on cardiovascular parameters in obese individuals.

This study aims to evaluate the long-term effects of endurance training as a modulator in the prevention of cardiovascular disease risk in obese individuals. Specifically, this study aims to demonstrate the effects of eight weeks of endurance training, performed three times per week, on improving systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), and resting heart rate (RHR) in obese women.

Material and Methods

Experimental Study

This study utilized a true-experimental design with a pretest-posttest control group approach. Twenty-five obese women meeting the following inclusion criteria were randomly assigned to either a control group (CNT, $n = 12$) or an exercise group (EXC, $n = 13$): age 20-25 years, body mass index (BMI) ≥ 27 -35 kg/m², body fat percentage ≥ 30 %, oxygen saturation 95-100 %, fasting blood glucose ≤ 100 mg/dL, and hemoglobin levels between 12-16 g/dL. Before participating, all participants were informed about the benefits, their right

to withdraw at any time, and any potential risks associated with the intervention program. They voluntarily provided informed consent. All study protocols were approved by the Ethics Committee of Universitas Negeri Malang on June 20, 2024 (Approval No. 20.06.9/UN32.14.2.8/LT/2024).

Endurance Training Programs

The endurance training program was implemented and supervised by personal trainers from Atlas Sports Club Malang. Each participant was accompanied by a personal trainer to ensure the proper execution of the endurance training program. The endurance training was conducted using a treadmill (T5 Treadmill, Life Fitness, Co., Ltd, USA) set at a 0 % incline and a moderate intensity (60-70 % of HRmax). Each session lasted 40-60 minutes and was held three times a week (Tuesday, Thursday, and Saturday) over eight weeks. Exercise intensity was based on HRmax, calculated as 200 minus the participant's age, and monitored using a Polar H10 heart rate sensor. The training environment was maintained at a controlled room temperature and humidity ($26 \pm 1^\circ\text{C}$ and 50-70 %, respectively).

Data Collection

Data collection involved measuring systolic and diastolic blood pressure using an automatic sphygmomanometer (OMRON HBP-9030; Omron Healthcare Co., Ltd, Osaka, Japan) (Pranoto et al., 2023), while resting heart rate was measured using a Polar H10 heart rate sensor (Polar Electric, Inc., Bethpage, NY, USA) (Rejeki et al., 2024). Assessments were conducted at baseline (pre) and after eight weeks (post) of endurance training. All assessments were performed in a temperature-controlled room (25°C) between 7:00 and 9:00 AM.

Statistical Analysis

Normality testing was conducted to observe data distribution using the Shapiro-Wilk test. Parametric tests, including paired sample t-tests, were used to assess within-group differences (time: pre vs. post), while independent sample t-tests were employed to assess between-group differences (group: CNT vs. EXC) at a 95 % confidence level. The effect size was evaluated using Cohen's d. All data are presented as mean $\pm$ standard deviation (SD). Statistical analysis was conducted using SPSS for Windows, version 21 (SPSS Inc., Chicago, IL, USA).

Results

Participant's Characteristics in Research

All 25 obese women in both the CNT and EXC groups completed the baseline (pre) and eight-week (post) assessments with no dropouts observed (dropout rate = 0 %). Table 1 presents the analysis of participant characteristics, revealing no significant differences between the groups in age, anthropometric measurements, body fat percentage, resting heart rate, blood pressure, mean arterial pressure, oxygen saturation, fasting blood glucose, or hemoglobin levels (all $p \geq 0.05$).

Table 1. General characteristics of participants

Variable	CNT, n = 12	EXC, n = 13	p-value
Age (yrs)	22.25 ± 1.76	22.39 ± 1.26	0.827
Weight (kg)	73.68 ± 6.29	72.46 ± 8.99	0.698
Height (m)	1.57 ± 0.06	1.55 ± 0.05	0.386
BMI (kg/m ²)	30.07 ± 1.15	30.27 ± 2.52	0.806
PBF (%)	34.40 ± 2.53	33.49 ± 4.39	0.527
SpO ₂ (%)	97.83 ± 1.12	98.08 ± 0.95	0.562
FBG (mg/dL)	91.00 ± 5.75	88.77 ± 6.74	0.384
Hb (g/dL)	14.83 ± 1.41	14.89 ± 1.36	0.927
Baseline SBP (mmHg)	127.72 ± 1.81	126.23 ± 2.98	0.144
Baseline DBP (mmHg)	83.75 ± 3.21	85.65 ± 3.03	0.142
Baseline MAP (mmHg)	98.41 ± 2.68	99.18 ± 2.18	0.438
Baseline RHR (bpm)	81.29 ± 2.21	80.96 ± 3.09	0.763

Effects of exercise on blood pressure, MAP, and RHR

Analysis results of blood pressure (BP), mean arterial pressure (MAP), and resting heart rate (RHR) are presented in Table 2 and Figures 1-4. A significant reduction in systolic blood pressure (SBP), diastolic blood pressure (DBP), MAP, and RHR was detected in the EXC group from pre- to post-training (all $p \leq 0.001$). In contrast, no significant changes were observed in the CNT group for SBP, DBP, MAP, and RHR (all $p \geq 0.05$).

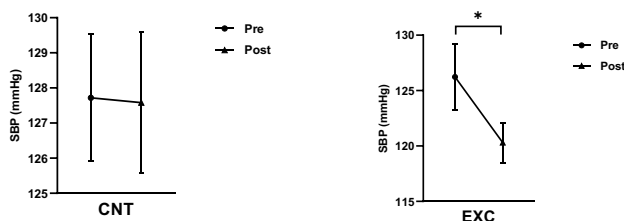


Fig. 1. SBP (mmHg) assessment at pre and post-endurance training. *Significant at pre in EXC group ($p \leq 0.001$). Data are presented as mean $\pm$ SD

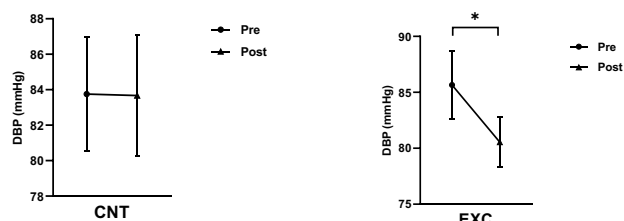


Fig. 2. DBP (mmHg) assessment at pre and post-endurance training. *Significant at pre in EXC group ($p \leq 0.001$). Data are presented as mean $\pm$ SD

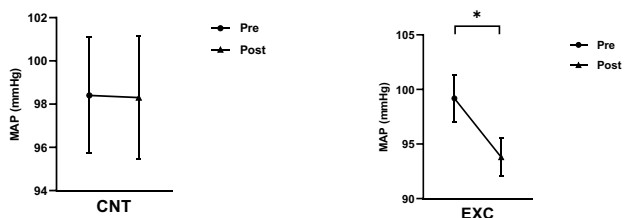


Fig. 3. MAP (mmHg) assessment at pre and post-endurance training. *Significant at pre in EXC group ($p \leq 0.001$). Data are presented as mean $\pm$ SD

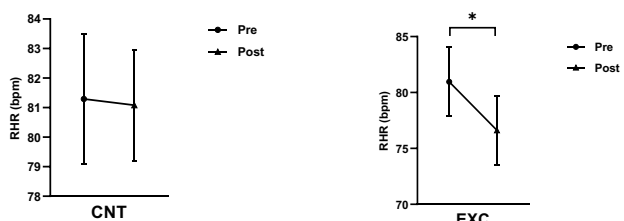


Fig. 4. RHR (bpm) assessment at pre and post-endurance training. *Significant at pre in EXC group ($p \leq 0.001$). Data are presented as mean $\pm$ SD

Discussion

Eight weeks of endurance training, performed three times per week, resulted in significant reductions in systolic blood pressure (SBP), diastolic blood pressure (DBP),

Table 2. Blood pressure, MAP, and RHR assessment at baseline (pre) and week 8 (post)

Variable	Mean (SD)		95% CI		p-value	ES d
	CTN, n=12	EXC, n=13	Lower	Upper		
Pre-SBP, mmHg	127.72 (1.81)	126.23 (2.98)	-0.56	3.53	0.144	0.602
Post-SBP, mmHg	127.58 (2.02)	120.31 (1.79)*	5.69	8.87	0.000	3.804
Δ -SBP, mmHg	-0.13 (1.20)	-5.92 (2.19)*	4.33	7.25	0.000	3.281
Pre-DBP, mmHg	83.75 (3.21)	85.65 (3.03)	-4.49	0.69	0.142	0.610
Post-DBP, mmHg	83.67 (3.39)	80.54 (2.22)*	0.71	5.55	0.014	1.091
Δ -DBP, mmHg	-0.08 (1.62)	-5.12 (1.62)*	3.69	6.38	0.000	3.102
Pre-MAP, mmHg	98.41 (2.68)	99.18 (2.18)	-2.82	1.26	0.438	0.317
Post-MAP, mmHg	98.31 (2.84)	93.79 (1.76)*	2.51	6.52	0.000	1.911
Δ -MAP, mmHg	-0.10 (1.46)	-5.39 (1.16)*	4.18	6.39	0.000	4.008
Pre-RHR, bpm	81.29 (2.21)	80.96 (3.09)	-1.89	2.55	0.760	0.123
Post-RHR, bpm	81.08 (1.88)	76.62 (3.09)*	2.35	6.59	0.000	1.743
Δ -RHR, bpm	-0.21 (1.57)	-4.35 (1.93)*	2.69	5.59	0.000	2.351

Data are presented as mean $\pm$ SD. *Significant at CNT group ($p \leq 0.01$). ES d: Effect size Cohen's d

mean arterial pressure (MAP), and resting heart rate (RHR) among obese individuals. These reductions indicate improvements in cardiovascular function, which have direct implications for lowering cardiovascular disease (CVD) risk. Endurance training, which involves moderate- to high-intensity physical activity, enhances vascular elasticity and reduces peripheral vascular resistance (Zhang et al., 2024; Weston et al., 2022; Shishira et al., 2024). Repeated exercise sessions improve endothelial function through increased blood flow, which reduces blood pressure by decreasing vasoconstriction (Tanaka et al., 2024; Parvanova et al., 2023). For obese individuals, who generally exhibit higher peripheral resistance, these physiological adaptations are crucial for alleviating the typically elevated blood pressure burden compared to non-obese individuals (Gallo et al., 2024).

The significant reduction in RHR in the intervention group reflects an increase in cardiac efficiency (Moncion et al., 2024). Endurance training enhances stroke volume, which is the amount of blood pumped per heartbeat (Bennett & Solberg, 2023). This adaptation enables the heart to work more efficiently, requiring fewer beats to meet the body's needs at rest and during light physical activity (Scott et al., 2024). This reduction in RHR is a key indicator of increased aerobic capacity and overall heart health (Pozuelo-Carrascosa et al., 2021). Therefore, endurance training not only improves physical fitness but also reduces the heart's workload over the long term (Seo et al., 2023).

The findings of this study are consistent with previous research that has also reported the benefits of endurance training on cardiovascular parameters (Weaver et al., 2022). For example, a study by Jabbarzadeh Ganjeh et al. (2024) found that endurance training performed for 30 minutes weekly lowered SBP by 1.78 mmHg in patients with hypertension. Similarly, a meta-analysis by Reimers et al. (2018) reported that, after an average of 14 weeks of endurance training, participants showed a significant reduction in RHR compared to non-exercisers, with gender-based reductions ranging from 4.5% to 9.0% and 2.7 to 5.8 bpm, respectively. Although the duration of the current study's program was shorter (8 weeks), the results indicate that a moderate-frequency training regimen is sufficient to produce significant improvements in obese individuals. The fact that a relatively short and simple training intervention can lead to cardiovascular benefits in this population underscores the effectiveness of endurance training as a preventive intervention.

A major strength of this study is its simple, widely applicable intervention design. Conducting endurance training three times per week for eight weeks is an intervention that is feasible to implement in various clinical and community settings. This adds practical relevance to the study's findings, as a straightforward exercise program can be adopted independently by obese individuals with high cardiovascular risk. Additionally, the use of objective measurements such as SBP, DBP, MAP, and RHR, which are commonly used indicators of cardiovascular risk, makes these findings easily comparable to similar studies (Jiang et al., 2024; Choi et al., 2024).

Endurance exercise interventions can impact several physiological mechanisms associated with lowering blood pressure and RHR (Jabbarzadeh Ganjeh et al., 2024; Weaver

et al., 2022). One primary mechanism is the reduction in sympathetic nervous system activity, which is typically hyperactive in obese individuals (Tanaka, 2020; Parvanova et al., 2023). Decreased sympathetic activity reduces catecholamine release, which is involved in vasoconstriction, thus promoting vasodilation and reducing vascular resistance (Motiejunaite et al., 2021). Increased stroke volume, as an adaptation of the heart to exercise, also contributes to a lower RHR (Wolsk et al., 2021). With increased cardiac efficiency, the resting heart rate can be lower, as the heart pumps more blood per beat (Bennett & Solberg, 2023).

The clinical implications of these findings are significant for the prevention of cardiovascular disease in obese individuals. The reductions in SBP, DBP, MAP, and RHR demonstrate that a simple yet consistent endurance training regimen can serve as an effective non-pharmacological intervention to lower the risks of hypertension, stroke, and coronary heart disease. Integrating endurance training programs into the management of obesity and cardiovascular risk provides a low-cost, safe, and accessible preventive measure with beneficial outcomes for high-risk individuals.

While the positive outcomes observed in this study are promising, certain limitations must be acknowledged. First, the intervention duration of only 8 weeks may not be sufficient to observe the long-term effects of endurance training, particularly regarding sustained reductions in CVD risk. Some vascular or metabolic adaptations require longer periods to stabilize and demonstrate their full effects (Green et al., 2017). Therefore, long-term studies are necessary to determine whether the cardiovascular benefits observed can be maintained or further enhanced over time. Second, this study focused on blood pressure and RHR parameters without including additional measures such as VO_2max , lipid profiles, or inflammatory markers. Including these parameters would provide a more comprehensive understanding of how endurance training affects metabolic and cardiovascular health.

Conclusion

The results of this study indicate that eight weeks of endurance training performed three times weekly consistently reduced SBP, DBP, MAP, and RHR in obese individuals. These findings highlight the potential of endurance training as an effective intervention for preventing cardiovascular disease risk in individuals with obesity. However, further research is needed to explore the long-term effects and to incorporate other relevant parameters to enrich the understanding of the physiological mechanisms underlying these changes.

Conflict of Interest

The authors declare that they have no conflicts of interest.

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Довготривалі тренування з розвитку витривалості як модулятор профілактики ризику серцево-судинних захворювань у осіб з ожирінням

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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. Метою цього дослідження було визначити довгостроковий вплив тренувань з розвитку витривалості як модулятора профілактики ризику серцево-судинних захворювань у осіб з ожирінням.

Матеріали та методи. У дослідженні застосовано метод «істинного експерименту», що включає претест-посттестовий дизайн контрольної групи. Двадцять п'ять жінок з ожирінням віком 20-30 років, які мали показник відсоткового вмісту жиру в організмі $\geq 30\%$, було розподілено на контрольну групу (КГ) та групу, що виконувала фізичні вправи (ФВГ). ФВГ проходила восьмитижневу (три заняття на тиждень) програму тренувань з розвитку витривалості (із використанням бігової доріжки) з тривалістю заняття 40-60 хвилин. Вимірювання кров'яного тиску (КТ), середнього артеріального тиску (САТ) та частоти серцевих скорочень (ЧСС) у стані спокою проводили за допомогою цифрового тензіометра OMRON HBP-9030 та датчика частоти серцевих скорочень Polar H10 на початку (передтренувальний етап) та через вісім тижнів (посттренувальний етап) виконання фізичних вправ з розвитку витривалості.

Результати. Встановлено значне зниження показників систолічного артеріального тиску (САТ), діастолічного артеріального тиску (ДАТ), середнього артеріального тиску і ЧСС у стані спокою між етапами перед початком і після завершення програми тренування на витривалість (всі показники на рівні $p \leq 0,001$). Крім того, між групами спостерігалось суттєве зниження систолічного артеріального тиску, діастолічного артеріального тиску, середнього артеріального тиску і ЧСС у стані спокою (всі показники на рівні $p \leq 0,05$).

Висновки. Отримані дані свідчать про ефективність застосування програми щодо виконання восьмитижневих тренувань з розвитку витривалості, що сприяє послідовному зниженню показників систолічного артеріального тиску, діастолічного артеріального тиску, середнього артеріального тиску і ЧСС у стані спокою у жінок з ожирінням.

Ключові слова: кров'яний тиск, серцево-судинні захворювання, ожиріння, фізичні вправи.

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Evaluating the Relationship between Physiological Parameters and Performance of Female Swimmers in the 200 m Individual Medley

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Abstract

Objectives. The primary objective of this study was to evaluate the selected physiological parameters and performance of female swimmers in the 200 m individual medley, analysing the contribution of selected physiological variables and construction of predictive model.

Materials and methods. The study involved forty female swimmers, who were recruited from the state of West Bengal, India. This selection specifically targeted individuals who had actively engaged in the demanding disciplines of the 200 m individual medley swimming events. Furthermore, subjects were carefully selected from the age group spanning 17 to 25 years. After quantifying physiological parameters, swimmers performed a 200 m individual medley test. A value of $\alpha = 0.05$ was used for all tests as the criterion to determine the presence or absence of significance. Pearson's product moment correlation coefficient (r) was used for assessing the various relationships of the selected variables towards the performance in the 200 m individual medley.

Results. A significant relationship was found between $VO_2\max$ ($r = -0.562$), body fat percentage ($r = -0.643$) and swimming performance in the 200 m individual medley event at the 1 % significance level. Multiple linear regression was used for evaluating the contribution of identified physiological variables and construction of predictive model. The regression equation was found to be reliable, as demonstrated by the value of r^2 being 0.54. The two independent variables explain 54.00 % variations in the 200 m individual medley event among female swimmers.

Conclusions. The F-value for the regression model was determined as highly significant, indicating the reliability of the model. This study provides a further understanding of the physiological variables associated with skilled performance in the women's 200 m individual medley event, which coaches should consider when training less skilled female swimmers.

Keywords: individual medley, female swimmer, $VO_2\max$, body composition, regression.

Introduction

Swimming is a famous game and early beginning specialization in spite of the fact that exhibition and progress in world class swimmers rely upon different elements. Competitive swimming is formed by 50 to 1,500 m distances utilizing four individual and combined (medley) swimming methods (Pyne & Sharp, 2014). Medley swimming is a difficult and flexible discipline inside serious swimming that includes a mix of four different swimming styles in a single race. In the medley, swimmers should perform equivalent distances of every one of the four strokes in the

accompanying request: butterfly, backstroke, breaststroke, and freestyle. One of the vital physiological boundaries in sports is high-impact limit, frequently estimated through boundaries like $VO_2\max$ (maximal oxygen utilization) and $VO_2\max$ reflects the most extreme measure of oxygen a competitor can use during extraordinary activity and is an essential determinant of perseverance and cardiovascular wellness. A higher $VO_2\max$ shows a more noteworthy vigorous limit and the capacity to support focused energy endeavours for longer terms. $VO_2\max$ is utilized to assess physiological capacity and is connected with oxygen take-up, transport and use by the body, deciding as far as possible for oxidative energy creation (Poole & Jones, 2017). At the point when it is unimaginable to expect to notice a VO_2 level, oxygen consuming capacity can be assessed by the

most elevated enrolled esteem VO_2 peak (Ribeiro et al., 2015). Body composition implies the sort and proportion of tissues which make up the body. It contains the degrees of muscle versus fat and fit body weight. Complete body weight is considered as a construction of "fat" weight and "lean" weight. Muscle to fat ratio is organized as either central or amassing fat (McArdle, Kalch & Katch, 1991). The use of skinfold thickness in the assessment of no less than one body districts is a strong strategy for perceiving the percent of muscle versus fat from lean body mass (Hoeger & Hoeger, 1992). Body composition is a term that depicts the overall extents of all fundamental parts of the body, including fat, bone, muscle, and water accumulation (Ratamess, 2012). Assessing the relationship of body composition to swim execution on the example of 280 serious female swimmers it was found that Body Level, Weight, Lean Weight (LBM), and Residual Lung Volume were in connection, which is genuinely huge yet backwards to the time recorded for the 100-yard swim (Stager & Cordain, 1984). During competitive swim season, huge increment of Lean Weight and reduction of fat mass has happened basically during the piece of the time while preparing was extreme (Meleski & Malina, 1985). Lean body mass, which essentially reflects bulk, starts to increment during early adolescence in the two genders. Fat mass, nonetheless, increments during the late phases of adolescence in young ladies. A further expansion in fat mass after pubescence might hinder swim execution in ladies. Moreover, development is prior in ladies than in men (Wheeler, 1991).

Physiological boundaries are fundamental to sports execution as they give fundamental data to competitors and mentors. Evaluations of physiological boundaries of swimmers assist with fitting preparation programs, further develop execution, and limit the risk of injuries. Competitors with an extensive comprehension of their physiological profiles are better prepared to succeed in their particular games and arrive at their maximum capacity. As far as anyone is concerned, no examinations have researched the impact of various physiologic and specialized boundaries together to decide 200 m medley swimming performance in young female swimmers. Likewise, the reason for this study was to explore the physiological boundaries as indicators to swimming execution in individual 200 m medley event. Thus, we expect to assess the distributed proof and research the connection between physiological boundaries and execution of female swimmers in 200 m individual medleys. The following research questions were examined: (I) what were the various relationships of the identified parameters with the swimming performance in 200 m Individual Medley Event of female swimmers? (II) is there the contributions of identified parameters towards the 200 m Individual Medley Event of female swimmers?

Materials and Methods

Study Participants

Forty young adult female swimmers (19.0 ± 1.0 years) took part in the study. All swimmers had a preparation foundation of five to six years and throughout the past one year they had been rehearsing for six to seven hour/week. Swimmers were enlisted from the province of West Bengal,

nearby swimming clubs on a voluntary basis. Swimmers who did not prepared for over about a month and introduced wounds or infection that could think twice about tests were barred. Furthermore, a composed informed assent was gotten from the subjects before participation.

Study Organization

Physiological Parameters Measurement and 200 m Individual Medley Swimming Test

Cardio-respiratory Fitness (VO_{2max}) was estimated by the accompanying method $VO_{2max} = 15.3 \times (HR_{max}/HR_{rest})$. MHR in this formula is calculated through $208 - (0.7 \times \text{Age})$ and Body Composition (Body Fat %, Lean Body Mass) was estimated by Omron Karada Scan Body Composition Monitor (Model HBF-375), furnished with exclusive programming. The 200 m Individual Medley swimming performance was performed in a swimming pool, with the start of the trial taking place in the water. 200 m Individual Medley swimming performance was taken following appropriate measures as per official regulation of World Aquatics formerly known as FINA in Standard Swimming Pool and the timing was taken.

Statistical Analysis

The normality of distribution was surveyed on all information utilizing the Shapiro-Wilk test. Means, standard deviations, minimum and maximum values were calculated for all parameters. Pearson's Product Moment Correlation was applied to assess how effectively the distinguished boundary is related with the swimming performance in 200 m Individual Medley Event of female swimmers. Stepwise linear regression analyses were utilized for assessing the commitment of distinguished factors and development of prescient model. A value of $\alpha = 0.05$ was used for all tests as the criterion to determine the presence or absence of significance. SPSS for Windows, version 20.0; (SPSS Inc.; Chicago, IL) was utilized for all examinations.

Results

Before discussing the research issues the nature of the variable were analysed through Descriptive Statistics which have been presented in Table 1. Pearson's Product Moment Correlation which has been presented in Table 2. Multiple Linear Regression analysis which have been presented in Table 3.

The mean and standard deviation scores of VO_{2max} of the subjects was 36.20 ± 5.45 , standard error of mean, variance of VO_{2max} was 0.86, 29.70, for Body Fat Percentage mean and standard deviation of subjects was 15.56 ± 4.14 , standard error of mean, variance of Body Fat % was 0.65, 17.11, and for Lean Body Mass mean and standard deviation of subjects was 50.18 ± 5.35 , standard error of mean, variance of Lean Body Mass was 0.85, 28.63.

For testing the normality of the data skewness and kurtosis has been carried out. The data was found normal in the variables of Physiological parameters of female swimmers, it can be purely considered as a normal because the data sets skewness was within the permissible limit as

Table 1. Descriptive statistics on selected physiological parameters of the examined swimmers

Variables	Minimum	Maximum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
VO ₂ max	26.00	52.00	36.20	0.86	5.45	29.70
Body Fat Percentage	7.20	22.40	15.56	0.65	4.14	17.11
Lean Body Mass	40.18	60.60	50.18	0.85	5.35	28.63

Valid N (listwise) 40

Table 2. Normality distribution of data

Skewness		Kurtosis	
Statistic	Std. Error	Statistic	Std. Error
0.73	0.37	1.69	0.73
-0.40	0.37	-0.71	0.73
-0.19	0.37	-0.47	0.73

the values of skewness for the data sets were less than twice the value of standard error of skewness, and hence all the variables were symmetrically distributed. Similarly, Kurtosis was also within the permissible limit as the values of kurtosis for the data sets were less than twice the value of standard error of Kurtosis. Except the variable VO₂max the value of kurtosis for the data sets were more than twice the values of standard error of Kurtosis. This demonstrates that less variety exists around their mean value.

Table 3. Pearson's correlation coefficient between physiological parameters and performance in 200 m individual medley event

Identified Variables	Correlation Coefficient female (n=40)
VO ₂ max	-0.562**
Body Fat %	-0.643**
Lean Body Mass	-0.080

** p < 0.01 (2-tailed). * p < 0.05 (2-tailed). **Significant value of the correlation coefficient at 0.01 level with 38 df = 0.403.

*Significant value of the correlation coefficient at 0.05 level with 38 df = 0.312

In female swimmers, significant correlations were found between the VO₂max (r = -0.562), Body Fat % (r = -0.643) and the swimming performance in 200 m Individual Medley Event at 1 % level; found greater than critical value of r. A negative correlation was found in female between the identified parameters and swimming performance in 200 m Individual Medley Event. Whereas no significant correlations were revealed between Lean Body Mass (r = -0.080) and the

swimming performance in 200 m Individual Medley Event of female swimmers. Thus, r values of Lean Body Mass were found less than critical values of r at 5 % and 1 %, respectively.

Table 4 reveals that 200 m Individual Medley swimming performance on the basis of identified Physiological parameters. Two regression models have been presented in Table 3. After analyzing with stepwise multiple regressions method, the value of R² in the first model is 0.41. But in the second model, the value of R² is 0.54, which was highest and, therefore, second model was used to build up the regression equation. The second model two independent variables, viz. Body Fat Percentage, Lean Body Mass have been identified and therefore, the regression equation was developed based on these two variables only. Since, these two independent variables explain 54.00 % variations in 200 m Individual Medley event of female swimmers.

Table 5. ANOVA table showing F-values for all the two models

Model	Sum of Squares	df	Mean Square	F	Sig.
1 Regression	9281.37	1	9281.37	26.76	0.000 ^b
Residual	13180.53	38	346.86		
Total	22461.90	39			
2 Regression	12129.55	2	6064.78	21.72	0.000 ^c
Residual	10332.35	37	279.25		
Total	22461.90	39			

a. Dependent Variable: 200 m Individual Medley (Seconds)

b. Predictors: (Constant), Body Fat Percentage

c. Predictors: (Constant), Body Fat Percentage, Lean Body Mass

n = 40; *Significant at 0.05 level

Table 5 reveals that F-values for all the models have been shown. The F-value for the second model was highly significant; it concluded that the model selected was highly efficient also. Also, the other model has significant but the value of R² for this model was less than second model.

Table 4. Model summary along with the values of R and R² for female swimmers

Model	R	R ²	Adjusted R Square	Std. Error of the Est.	Change Statistics				
					R ² Chg.	F Chg.	df1	df2	Sig. F Chg.
1	0.643 ^a	0.41	0.40	18.62	0.41	26.76**	1	38	0.00
2	0.735 ^b	0.54	0.52	16.71	0.13	10.20**	1	37	0.00

a. Predictors: (Constant), Body Fat Percentage

b. Predictors: (Constant), Body Fat Percentage, Lean Body Mass

Dependent Variable: Swimming performance in 200 m Individual Medley Event. n = 40; ** p < 0.01 and * p < 0.05

Table 6. Regression coefficients of physiological parameters to the swimming performance on 200 m individual medley event of female swimmers

	Model	Unst. Coeff.		St. Coeff.	t	Sig.	Correlations		
		B	SE	Beta			r _{xy}	Partial	Part
1	(Constant)	261.46	11.60		22.55	0.00			
	Body Fat Percentage	-3.73	0.72	-0.64	-5.17	0.00	-0.64	-0.64	-0.64
2	(Constant)	361.86	33.11		10.93	0.00			
	Body Fat Percentage	-4.60	0.70	-0.79	-6.55	0.00	-0.64	-0.73	-0.73
	Lean Body Mass	-1.73	0.54	-0.39	-3.19	0.00	-0.08	-0.47	-0.36

a. Dependent Variable: 200 m Individual Medley (Seconds)

** p < 0.01 and * p < 0.05. (Abbreviations: Unst. Coeff. – Unstandardized Coefficients, St. Coeff. – Standardized Coefficients, SE – standard error, r_{xy} – Zero-order)

Table 6 reveals that the unstandardized and standardized regression coefficient in all the two models. In the second model t-values for the entire regression coefficient were significant as there significant values (p-values) were less than 0.01. Thus, it concluded that the variables; Body Fat Percentage, Lean Body Mass significantly explains the variations in the 200 m Individual Medley swimming performance of female swimmers. In order to know which is the most contributing predictor in the model out of those two variables we should look for Beta Coefficient in Table 6. Larger the absolute value of Beta coefficient more is the contribution of that variable in the model. Thus, Body Fat Percentage is the most contributory predictor in the model.

Regression Equation

The unstandardized regression coefficients (B) of the second model shown in Table 5, the regression equation was developed which was:

Performance in 200 m Individual Medley Event (Female) = 361.86 – 4.60 × (Body Fat %) – 1.73 × (Lean Body Mass)

Discussion

Present study was directed with the reason to research the connection between physiological parameters and performance of female swimmers in 200 m individual medleys. For simplicity of conversation and lucidity in understanding the discoveries has been talked about. Results uncovered that some of the physiological parameters, significant correlations were found between the VO₂max (r = -0.562), Body Fat % (r = -0.643) and the swimming performance in 200 m Individual Medley Event at 1 % level; found greater than critical value of r. One more review showed relationship between ladies' swimming presentation and level, percent body endlessly fat free weight in competitive collegiate swimmers (Siders, Lukaski, & Bolonchuk, 1993). Youth swimming performance might be impacted by anthropometric, physiology and specialized factors. Execution of youthful swimmers in the 100 meters front crawl is resolved overwhelmingly by physiological factors and swimming procedure (Vitor & Böhme, 2010). The hypothesis as stated earlier that there may be significant relationship of identified variables to the performance in 200 m individual medleys and the identified variables may significant contributors of 200 m individual medleys. Whereas no significant correlations were revealed

between Lean Body Mass (r = -0.080) and the swimming performance in 200 m Individual Medley Event of female swimmers. The detriment of having higher fat mass proposes that swimmers require more prominent lean body mass and more prominent muscle solidarity to push them quicker through the water. In equal, higher fat mass might force expanded upsides of body cross-sectional region and, thusly, complete drag. A bigger lean weight and, in this manner, a more prominent bulk, could emphatically impact bio-mechanical values by upgrading the power applied in every upper appendages cycle (Pelayo, Sidney, Kherif, Chollet, & Tourny, 1996). Expanding muscle size and improvement of muscle contractile quality, and diminishing fat mass, at a degree of ideal equilibrium, may affect swimming execution, and is probably going to be significant for boosting serious swimming execution. Also, occasional swim execution changes will generally follow changes in bulk, so customary control of body piece during the season might be useful and helpful to progress preparing and execution (Roelofs, Emith-Ryan, Trexler, & Hirsch, 2017). Table 3 reveals that 200 m Individual Medley swimming performance on the basis of identified Physiological parameters. After analyzing with stepwise multiple regressions method the value of R² in the first model is 0.41. But in the second model, the value of R² is 0.54, which was highest and, therefore, second model was used to build up the regression equation. The second model two independent variables, viz. Body Fat Percentage, Lean Body Mass have been identified. Since, these two independent variables explain 54.00 % variations in 200 m Individual Medley event of female swimmers which are relatively excellent. Jürimäe et al. (2007) uncovered that in-water VO₂peak (R² = .358), and arm span (R² = .454) were the best indicators of swimming execution. The retrogressive extrapolation technique could be utilized to survey VO₂peak in youthful swimmers. Arm span, and VO₂peak give off an impression of being the significant determinants of front-crawl swimming performance in youthful swimmers. In our study, the F-value for the second model was highly significant; it concluded that the model selected was highly efficient also. In the second model t-values for the entire regression coefficient were significant as there significant values (p-values) were less than 0.01. Thus, it concluded that the variables; Body Fat Percentage, Lean Body Mass significantly explains the variations in the 200 m Individual Medley swimming performance of female swimmers. In order to know which is the most contributing predictor in the model out of those

two variables we should look for Beta Coefficient in Table 5. All the more by and large many swimming trainers regularly advocate around 15 % body fat as an upper-end cut-off for elite female swimmers. The body fat percentage of a functioning competitor is many times below the normal individual. Anyway, in our review we can obviously saw that the mean worth of Body Fat Percentage was 15.56 %, which is good enough. From the investigation of Santos et al. (2014), showed that the worldwide sprint swimmers both men and women are taller, with less body fat, with lower body mass index, yet with a more significant level of contractile, i.e., muscle mass, than national level swimmers. Body fat influences swimming pace in various ways. Since fat is less thick than other body constituents, expanding body fat will in general make you lighter, which can lift you higher in the water, diminish drag and maybe make swimmer quicker. In competitors, weight can be a mark of the dynamic bulk. In any case, an expansion in weight can likewise be a mark of high upsides of muscle mass. However, an increase in body mass can also be an indicator of high values of body fat mass. Muscle mass can represent body strength of the swimmer; on the off chance that these qualities are low, a decline in swimming execution might be normal. It ought to be viewed as that weight doesn't recognize and address lean weight or muscle versus fat mass extents thus, for a more definite assessment; these factors ought to be estimated freely.

Conclusions

Considering the purpose along with objectives of the study, based on the analysis and within the limitations of present investigation, conclusions derived were: The selected average values of different identified variables had contribution at the time of 200 m individual medley. Result of the minimum and maximum scores was provided a boundary of identified variable scores at the time of swimming. The physiological parameter namely VO_2max , and Body Fat Percentage was found significantly related with the swimming performance in 200 m Individual Medley Event at 1 % level. Body Fat Percentage and Lean Body Mass were valid in estimating the performance in 200 m individual medley swimming. The model developed in the present study helps the professionals for predicting the swimming performance of the female in 200 m medley. In this dimension there is lack of critical literature and thus demands focus for future researches. Such research is essential to develop separate coaching protocols for 200 m individual medley and should be pursued in many aspects of sports physiology. We hope this study has distinguished the need to make more extensive the strategy utilized while attempting to improve any brandishing execution.

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Conflict of Interest

The authors declare that they have no conflicts interests.

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Оцінювання взаємозв'язку між фізіологічними параметрами та результативністю плавчинь в індивідуальному комплексному плаванні на дистанції 200 м

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

Реферат. Стаття: 6 с., 6 табл., # рис., 15 джерел.

Мета дослідження. Основна мета цього дослідження полягала в оцінюванні обраних фізіологічних параметрів і результативності плавчинь, які беруть участь в індивідуальному комплексному плаванні на дистанції 200 м, аналізуючи вплив обраних фізіологічних змінних і побудову прогностичної моделі.

Матеріали та методи. Для проведення дослідження було відібрано сорок плавчинь зі штату Західна Бенгалія (Індія). Даний відбір був спеціально орієнтований на осіб, які активно брали участь у змаганнях з індивідуального комплексного плавання на дистанції 200 м, що є складною дисципліною, яка вимагає від спортсменів значних зусиль. Крім того, суб'єктів дослідження було ретельно відібрано з вікової категорії від 17 до 25 років. Після проведення кількісної оцінки фізіологічних параметрів, плавчині виконали тест на дистанції 200 м індивідуальним комплексним плаванням. Значення $\alpha = 0,05$ було застосовано для всіх тестів як критерій визначення наявності або відсутності значущості. Коефіцієнт кореляції Пірсона (r) застосовувався для оцінки різних взаємозв'язків обраних змінних стосовно показників результативності в індивідуальному комплексному плаванні на дистанції 200 м.

Результати. Встановлено значущий взаємозв'язок між показниками максимального споживання кисню (VO_{2max}) ($r = -0,562$), відсоткового вмісту жиру в організмі ($r = -0,643$) та результативністю в індивідуальному плаванні на дистанції 200 м комплексним плаванням на рівні значущості 1 %. З метою оцінки впливу ідентифікованих фізіологічних змінних та побудови прогностичної моделі застосовано метод множинної лінійної регресії. Регресійне рівняння виявлено достовірним, про що свідчить значення r^2 , яке становить 0,54. Дві незалежні змінні пояснюють 54,00 % варіацій у змаганнях з індивідуального комплексного плавання на дистанції 200 м серед жінок.

Висновки. Встановлено високу значущість F-критерію для регресійної моделі, що вказує на її достовірність. Представлене дослідження забезпечує подальше розуміння фізіологічних змінних, пов'язаних з кваліфікованим виступом у змаганнях з індивідуального комплексного плавання на дистанції 200 м серед жінок, що тренери мають враховувати у процесі підготовки менш кваліфікованих плавчинь.

Ключові слова: індивідуальне комплексне плавання, плавчиня, максимальне споживання кисню (VO_{2max}), композиція тіла, регресія.

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Establishing the Interaction between Training Methods and Power Levels in Wrestling: A 2x3 Factorial Design of Hip Toss Skills

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Abstract

Objectives. This study aimed to evaluate the effects of resistance band exercises, good morning drills, and bicep curls on improving the hip throw technique among wrestling athletes, considering their initial power levels.

Materials and methods. This study employed a 2x3 factorial design involving 66 male students, grouped based on power levels (high and low) and training methods. The training was conducted over six weeks with a frequency of three weekly sessions. The measured parameters included improvements in hip throw technique skills, encompassing strength, stability, and execution speed. Data analysis was performed using ANOVA and Tukey's test to evaluate significant differences between groups.

Results. The results indicated a significant main effect of the training method factor (A) on hip toss skills ($F = 5.413$, $p = 0.007$), demonstrating that variations in training methods led to marked differences in skill outcomes. The second main effect, power level (B), showed an even more substantial influence ($F = 99.426$, $p = 0.000$), indicating that athletes' baseline power plays a crucial role in determining hip toss performance. Regarding the interaction effect, there was a considerable interaction between training methods and power levels ($F = 7.914$, $p = 0.001$).

Conclusions. This study concludes that resistance band exercises are the most effective method for athletes with high power in enhancing dynamic strength and flexibility relevant to hip toss techniques. The "good morning" exercise effectively supports postural stability, while bicep curls contribute to grip strength. A multidimensional approach integrating resistance band exercises, good morning drills, and bicep curls provides complementary benefits for improving hip toss technique skills in wrestling. These findings can serve as a foundation for coaches to design evidence-based training programs tailored to the specific needs of athletes.

Keywords: resistance band, good morning, bicep curl, hip toss, wrestling.

Introduction

Wrestling is a multidimensional sport that combines physical strength, technical skills, and psychological aspects to achieve optimal performance. Success in this sport is heavily influenced by dynamic strength, body composition, and aerobic endurance, which support rapid recovery and consistent performance during matches (Prokopczyk et al., 2024). The hip toss technique is a key wrestling skill that demands muscle strength, agility, and precise coordination (Mavropulo et al., 2022). However, developing this skill presents challenges, particularly in identifying the most effective training methods. One innovation in sports

training is using resistance bands, which have been proven to enhance muscle strength and flexibility and reduce the risk of injury, especially in combat sports like judo and mixed martial arts (Sivaraman et al., 2024). Other exercises, such as the "good morning" drill and bicep curls, have long been recognized for their effectiveness in supporting postural stability and grip strength, both essential for mastering the hip toss technique (Ceylan, 2023; Franco-López et al., 2024). Nevertheless, most previous studies have evaluated the effects of these methods individually without exploring the synergistic potential of combining these approaches (Devi et al., 2022; Ross et al., 2024).

Resistance bands have become a versatile and effective training tool for various sports, including wrestling. They play a central role in enhancing performance, particularly in

combat sports that require balance, stability, and explosive strength (Ilahi et al., 2023; Ioannides et al., 2024). Resistance bands can improve shoulder muscle strength, flexibility, and injury prevention, crucial for sports involving dynamic movements, such as wrestling (Francino et al., 2022; Sivaraman et al., 2024). Research indicates that resistance band exercises also support core muscle development, enabling athletes to maintain optimal posture during complex techniques like the hip toss. This is achieved through more efficient energy transmission along the kinetic chain (Devis et al., 2022; Harmanci et al., 2024; Luo et al., 2022; Sabillah et al., 2022).

The good morning exercise is another method with significant benefits for developing the lower back, gluteus, and hamstring muscles. Studies indicate that this exercise can enhance postural stability during explosive movements, which is highly relevant for techniques like hip tosses in wrestling (Franco-López et al., 2024). The good morning exercise provides critical stability during explosive actions by strengthening the lower back, gluteus, and hamstrings. However, compared to other exercises, particularly in lifting and controlling opponents during wrestling, its effects remain underexplored (Franco-López et al., 2024; Ross et al., 2024). The bicep curl exercise plays a vital role in improving arm strength. Research shows that greater arm strength helps wrestlers control their opponents during hip tosses (Ceylan, 2023; Matkarimov et al., 2024). Improved arm strength not only enhances technical performance but also boosts athletes' confidence, leading to overall better performance (Cherara et al., 2022).

While the benefits of resistance band exercises, good morning drills, and bicep curls have been individually recognized, research examining the combination of these three methods in the context of hip toss techniques in wrestling remains scarce. Most studies have focused solely on the effectiveness of each technique (Bavaresco et al., 2023; Coratella et al., 2023; Janep et al., 2024; Nuzzo et al., 2023; Oranchuk et al., 2020) without exploring the interactions or synergies between these training forms. The lack of empirical evidence on how the combination of resistance bands, good morning drills, and bicep curls can enhance hip toss skills, especially when considering differences in athletes' initial strength levels, presents an opportunity for further exploration. Baseline strength plays a critical role in the effectiveness of training methods; athletes with higher strength levels may respond better to intensive exercises like good morning drills, whereas resistance bands offer optimal benefits for those with lower strength levels due to the adjustable resistance they provide (Hoseini et al., 2022; Sabillah, 2023). A commonly proposed solution is to integrate various training methods into a multidimensional program, combining their unique benefits to address the specific needs of athletes and maximize their performance.

This study aims to address gaps in the existing literature by employing a multidimensional approach to enhance hip toss techniques in wrestlers. The multifaceted approach integrates three training methods: resistance band exercises, good morning drills, and bicep curls into a single training model to improve hip toss skills among wrestling athletes. This approach significantly contributes to the literature, which has predominantly focused on the individual effects of training methods on athletic performance (Francino et al., 2022; Ross et al., 2024). Using a 2x3 factorial design, this study not only compares the effectiveness of each training method

individually but also explores the synergistic interactions among the three methods, with athletes' baseline strength levels as a moderating variable. This focus is particularly relevant, as differences in athletes' initial strength levels may influence their responses to specific training methods (Hoseini et al., 2022; Sabillah, 2023).

The novelty of this research lies in integrating three training methods in the context of hip toss techniques. Resistance bands, for instance, are widely recognized for their ability to improve dynamic strength, flexibility, and injury prevention (Francino et al., 2022; Ioannides et al., 2024). This study extends these benefits by evaluating their role in supporting explosive movements and muscle flexibility, which are critical for executing hip toss techniques. Good morning exercises effectively strengthen the lower back, gluteus, and hamstrings—muscles essential for body stability during explosive movements (Franco-López et al., 2024). Meanwhile, bicep curls, though simple, provide the grip strength necessary for optimal control over opponents during hip tosses (Ceylan, 2023). This study explores synergies primarily overlooked in prior research by combining these three methods.

Additionally, this study emphasizes the importance of athletes' baseline strength in determining the effectiveness of applied training methods. Athletes with higher strength levels are predicted to respond better to intensive exercises like good morning drills. In comparison, resistance bands offer greater flexibility and are more suitable for athletes with lower strength levels (Hoseini et al., 2022). Thus, the research contributes new insights into how training methods can be personalized to maximize outcomes for athletes with different physical characteristics. Furthermore, the study focuses on evaluating hip toss skills through three critical phases: the initial position, execution, and final position. Unlike previous research, which often assessed overall performance outcomes, this approach provides an in-depth analysis of the training's effectiveness at each stage of technique execution (Sabillah, 2023).

This study is expected to uncover the mechanisms by which resistance band exercises, good morning drills, and bicep curls holistically enhance athletic performance. Using a factorial design also represents a methodological innovation in this research. This design enables simultaneous analysis of the interactions between training methods and athletes' baseline strength levels, providing insights into how variations in training combinations affect hip toss technique skills. The findings can produce evidence-based guidelines for coaches to design more personalized and effective training programs for competitive-level wrestlers (Devi et al., 2022; Harmanci et al., 2024). This study complements previous findings and challenges the assumption that all training methods yield similar impacts regardless of athletes' physical characteristics. The unique contribution of this research lies in offering evidence-based guidance for coaches to develop more tailored and effective training programs, enhancing training outcomes, and supporting the advancement of multidimensional training strategies in wrestling.

Materials and Methods

Study Participants

The study population comprised 200 male students from the Department of Physical Education, Health, and Recre-

ation, Faculty of Sports and Health Sciences, Makassar State University, aged 20 years or older. This age selection was based on previous studies indicating that individuals at this stage have achieved stable physical development, enabling a more valid analysis of the effects of training on muscle strength (Ross et al., 2024; Sabillah et al., 2022). The sample was randomly selected using a randomized group design. In the first step, the population was randomized to select 123 participants. The participants were then categorized based on their initial strength scores measured using the Rotational Power Ball Throw test. The top 27% of scores from each group were classified as high strength, while the lowest 27% were categorized as low strength. Scores falling between these categories were excluded to minimize potential analytical bias. Each strength category was subsequently divided into three groups based on the training method, resulting in six experimental groups comprising 11 participants.

Table 1. Experimental sample grouping

Power (B)	Training Methods (A)			Total
	Resistance Band (A ₁)	Good Morning (A ₂)	Bicep Curl (A ₃)	
High	11	11	11	33
Low	11	11	11	33
Total	22	22	22	66

Training Procedure and Instrument

The training program lasted six weeks, with three sessions per week, during which the duration and intensity were progressively adjusted to optimize results while minimizing the risk of injury. Before the program, all participants attended a detailed briefing on the training procedures, including execution techniques and training objectives. The presence of professional trainers during training sessions served as a control variable to ensure that all participants performed the exercises with proper technique. Trainer supervision not only ensured compliance with the protocols but also minimized injury risks and provided immediate feedback to enhance the quality of the training. Studies have indicated that direct supervision enhances training effectiveness by offering additional motivation and better technique corrections (Francino et al., 2022).

To enhance internal validity, external variables were strictly controlled. Participants were instructed not to engage in similar training outside the research program. Attendance at each training session was closely monitored, and participants missing more than two sessions were excluded from the study. The experimental groups were uniformly supervised to ensure all participants adhered to consistent protocols during the training sessions. The instruments used in this study included validated and reliable tools for assessing hip toss skills in wrestling performance (Roklicer et al., 2022). Skill assessments evaluated various aspects, such as technical accuracy (body positioning and opponent control), the strength of the toss, and the speed of execution. The hip toss skill test results were presented as an accumulated score derived from several evaluation indicators. The indicators for assessment focused on the movement patterns of the hip toss technique in wrestling, characterized by the following

descriptors: 1) Both wrestlers start standing with their weight balanced between both feet. 2) The wrestlers grip each other's hands while pressing their heads against each other. 3) The technique begins with a rotation where the left arm moves over the opponent's shoulder and around their neck. 4) The wrestler then performs a lifting motion using the hips while bending forward. 5) The opponent is thrown forward. The technique concludes with the opponent pinned to the mat by applying body pressure. These detailed descriptors ensured a comprehensive evaluation of the hip toss technique, providing a robust framework for assessing skill improvement.

Study Organization

This study employed a factorial design as a systematic approach to evaluate the effects of various training variables on athletic performance, particularly in wrestling. The factorial design allows for the simultaneous examination of interactions between variables, providing an advantage in analyzing the combined effects of multiple factors, such as training intensity, recovery strategies, and nutritional patterns, on athletic performance (T. Wang et al., 2022). A 2×3 factorial design was used to observe the effects of resistance band exercises, good morning drills, and bicep curls on hip toss skills among wrestlers with high and low power levels. This approach enables an in-depth analysis of how training methods and power categories interact to improve hip toss skills (Esmailnezhad et al., 2024; Kalaycioglu et al., 2022). The factorial design in this study involved the combination of two main factors: training methods (resistance band, good morning, and bicep curl) and athletes' power levels (high and low).

Table 2. 2×3 factorial research design

Attribute Variables	Treatment Variable	Training Methods (A)		
		Resistance band (A ₁)	Good Morning (A ₂)	Bicep Curl (A ₃)
Power (B)	High (B ₁)	A ₁ B ₁	A ₂ B ₁	A ₃ B ₁
	Low (B ₂)	A ₁ B ₂	A ₂ B ₂	A ₃ B ₂

Statistical Analysis

The research data were analyzed using analysis of variance (ANOVA) to evaluate the effects of training methods (resistance band, good morning, and bicep curl) and power levels (high and low) on hip toss skills. A 2×3 factorial ANOVA was employed to identify the main effects of the training methods and power levels and their interaction effects. This approach enables simultaneous analysis of multiple independent variables, comprehensively understanding each factor's contribution to the dependent variable. If the ANOVA results indicate significant differences ($p < 0.05$), a post hoc Tukey's Honest Significant Difference (HSD) test is conducted to determine which group pairs have substantial differences. The Tukey HSD test allows for precise mean comparisons across groups, making it possible to identify the most effective training method within specific categories (Pirruccio et al., 2022).

The application of the Tukey HSD test in this study aimed to evaluate several key aspects of hip toss skills in wrestling. These included differences between the resistance band training group and the good morning training group, between the resistance band training group and the bicep curl training group, and between the good morning training group and the bicep curl training group. The test also assessed the interaction effects between training methods and power levels on hip toss skills. Further analyses were conducted to explore differences within specific power categories. For students with high power levels, the Tukey HSD test compared the effectiveness of the resistance band training group with the good morning training group, the resistance band training group with the bicep curl training group, and the good morning training group with the bicep curl training group. Similarly, for students with low power levels, comparisons were made between the resistance band training group and the good morning training group, the resistance band training group and the bicep curl training group, and the good morning training group and the bicep curl training group. This comprehensive analysis aimed to provide detailed insights into the relative effectiveness of different training methods and their interactions with power levels in enhancing hip toss skills in wrestling.

Results

Descriptive analysis results indicate that the resistance band method (A_1) achieved the highest average score (Mean = 30.41) compared to good morning (A_2) (Mean = 25.45) and bicep curl (A_3) (Mean = 20.82), reaffirming its effectiveness in improving hip toss skills. Among athletes with high power, the resistance band method (A_1B_1) recorded the highest average score (Mean = 32.18) across all combinations, while it also remained superior in the low-power group (A_1B_2), with an average score of 25.36. The suitable morning method demonstrated moderate performance, with a higher average score than bicep curl in both the high-power group (Mean = 25.36) and the low-power group (Mean = 23.27), reflecting its contribution to enhancing postural stability. Conversely, the bicep curl method yielded the lowest average scores in

both the high-power (Mean = 19.18) and low-power groups (Mean = 18.36), suggesting that while this method is less optimal for hip toss techniques, it remains relevant for improving grip strength.

Resistance band exercises demonstrated the best performance with the highest concentration of scores in the upper intervals (30-36). Specifically, 27.3 % of participants scored within the 30-32 and 33-36 intervals, indicating that this method is highly effective in enhancing complex explosive skills. The good morning method exhibited a more even distribution, with the highest frequency concentrated in the 25-28 interval (31.8 %), reflecting its role in improving postural stability, albeit less optimal for dynamic skills. For the bicep curl method, most participants scored in the mid-to-upper range (29-32), with the highest relative frequency of 45.5 %. This indicates that bicep curls primarily support arm muscle strength but are less relevant for improving the dynamic strength required for technical skills.

The resistance band method (A_1B_1) exhibited a balanced frequency distribution in the upper intervals, with the highest concentration in the 24-36 range (27.3 % in each interval of 24-27, 28-31, and 32-36). This indicates that resistance bands are highly effective in enhancing technical skills among athletes with high power, supporting optimal dynamic strength development. The good morning method (A_2B_1) showed the highest concentration in the 28-31 interval (36.4 %), underscoring its role in improving postural stability in the high-power group. However, its contribution to enhancing explosive skills was lower compared to resistance bands, with a more even distribution across the lower to middle intervals. Conversely, the bicep curl method (A_3B_1) had the highest concentration in the lower to middle intervals (19-22) with a relative frequency of 54.5 %. This suggests that bicep curls are less effective for improving dynamic skills but remain relevant for supporting arm muscle strength, which is beneficial for grappling techniques.

The resistance band method (A_1B_2) demonstrated the highest concentration in the upper interval (31-34), with the highest relative frequency of 54.5 %. This finding indicates that resistance bands remain effective in the low-power group, supporting the gradual development of dynamic skills through adjustable resistance tailored to the

Table 3. Descriptive statistics of hip toss skill test results

Group	Resistance band (A_1)	Good Morning (A_2)	Bicep Curl (A_3)	Resistance band HP (A_1B_1)	Good Morning HP (A_2B_1)	Bicep Curl HP (A_3B_1)	Resistance band LP (A_1B_2)	Good Morning LP (A_2B_2)	Bicep Curl LP (A_3B_2)
N	22	22	22	11	11	11	11	11	11
	0	0	0	11	11	11	11	11	11
Mean	30.41	25.45	20.82	32.18	25.36	19.18	25.36	23.27	18.36
Median	31.00	25.50	20.50	34.00	27.00	18.00	25.00	23.00	19.00
Mode	31	25	20	34	28	14	20	23	16
Std. D	4.19	6.12	4.15	4.85	5.03	4.89	5.92	3.82	2.87
Varian	17.59	37.49	17.20	23.56	25.26	23.96	35.06	14.62	8.26
Range	15	20	18	16	15	16	18	14	8
Min	21	16	14	20	16	14	16	18	14
Max	36	36	32	36	31	30	34	32	22
Sum	669	560	458	354	279	211	279	256	202

Table 4. Frequency distribution of hip toss skills by training method

Training Method	Interval Class		Lower Limit	Upper Limit	Freq. Absolute	Freq. Relative	
Resistance Band	21	-	23	20.5	23.5	2	9.1 %
	24	-	26	23.5	26.5	3	13.6 %
	27	-	29	26.5	29.5	5	22.7 %
	30	-	32	29.5	32.5	6	27.3 %
	33	-	36	32.5	36.5	6	27.3 %
	Total					22	100 %
Good Morning	16	-	20	15.5	20.5	4	18.2 %
	21	-	24	20.5	24.5	4	18.2 %
	25	-	28	24.5	28.5	7	31.8 %
	29	-	32	28.5	32.5	3	13.6 %
	33	-	36	32.5	36.5	4	18.2 %
	Total					22	100 %
Bicep Curl	14	-	16	13.5	16.5	2	9.1 %
	17	-	20	16.5	20.5	3	13.6 %
	21	-	24	20.5	24.5	3	13.6 %
	25	-	28	24.5	29.5	4	18.2 %
	29	-	32	28.5	32.5	10	45.5 %
	Total					22	100 %

Table 5. Frequency distribution of hip toss skills by training method with high power

Training Method With High Power				Interval Class	Lower Limit	Upper Limit	Freq. Absolute	Freq. Relative
Resistance Band With High Power (A ₁ B ₁)	20	-	23	19.5	23.5	2	18.2 %	
	24	-	27	23.5	27.5	3	27.3 %	
	28	-	31	27.5	31.5	3	27.3 %	
	32	-	36	31.5	36.5	3	27.3 %	
	Total					11	100 %	
Good Morning With High Power (A ₂ B ₁)	16	-	19	15.5	19.5	2	18.2 %	
	20	-	23	19.5	23.5	3	27.3 %	
	24	-	27	23.5	27.5	2	18.2 %	
	28	-	31	27.5	31.5	4	36.4 %	
	Total					11	100 %	
Bicep Curl With High Power (A ₃ B ₁)	14	-	18	13.5	18.5	3	27.3 %	
	19	-	22	18.5	22.5	6	54.5 %	
	23	-	26	24.5	26.5	1	9.1 %	
	27	-	30	26.5	30.5	1	9.1 %	
	Total					11	100 %	

athletes' physical capabilities. The good morning method (A₂B₂) had the highest frequency concentration in the lower to the middle interval (18-21), with a relative frequency of 36.4 %, followed by two other middle intervals (22-25 and 26-29), each at 27.3 %. This distribution reflects that the good morning method improves postural stability but is less impactful in enhancing performance at higher score intervals. Conversely, the bicep curl method (A₃B₂) showed the most extensive distribution in the middle interval

(20-22), with a relative frequency of 45.5 %, while the other intervals had lower frequencies. This confirms that bicep curls are less effective in supporting hip toss skills in the low-power group, though they benefit grip strength and arm muscle development.

The first main effect, namely the training method factor (A), significantly influenced hip toss skills ($F = 5.413$, $p = 0.007$). This indicates that variations in training methods lead to significant differences in skill outcomes. The second

Table 6. Frequency distribution of hip toss skills by training method with low power

Training Method With Low Power	Interval Class			Lower Limit	Upper Limit	Freq. Absolute	Freq. Relative
Resistance Band With Low Power (A ₁ B ₂)	16	-	20	15.5	20.5	1	9.1 %
	21	-	25	20.5	25.5	1	9.1 %
	26	-	31	25.5	31.5	3	27.3 %
	31	-	34	30.5	34.5	6	54.5 %
	Total					11	100 %
Good Morning With Low Power (A ₂ B ₂)	18	-	21	17.5	21.5	4	36.4 %
	22	-	25	21.5	25.5	3	27.3 %
	26	-	29	25.5	29.5	3	27.3 %
	30	-	32	29.5	32.5	1	9.1 %
	Total					11	100 %
Bicep Curl With Low Power (A ₃ B ₂)	14	-	15	13.5	15.5	2	18.2 %
	16	-	17	15.5	17.5	3	27.3 %
	18	-	19	17.5	19.5	1	9.1 %
	20	-	22	19.5	22.5	5	45.5 %
	Total					11	100 %

Table 7. Summary of ANOVA results of hip toss skill data. Tests of between-subjects effects. Dependent variable: hip toss skill

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1729.212 ^a	5	345.842	25.216	.000
Intercept	43171.879	1	43171.879	3147.751	.000
A	148.485	2	74.242	5.413	.007
B	1363.636	1	1363.636	99.426	.000
A * B	217.091	2	108.545	7.914	.001
Error	822.909	60	13.715		
Total	45724.000	66			
Corrected Total	2552.121	65			

a. R Squared = .678 (Adjusted R Squared = .651)

main effect, the power level factor (B), also showed a much more substantial influence ($F = 99.426$, $p = 0.000$), highlighting that athletes' baseline power plays a key role in hip toss performance. Based on the interaction effect, there was a significant interaction between training methods and power levels ($F = 7.914$, $p = 0.001$). This demonstrates that the effectiveness of training methods varies depending on the athletes' initial power levels. The results indicate that both independent factors (training methods and power levels) significantly affect hip toss skills, and their interaction underscores the importance of selecting training methods appropriate to the athletes' initial power levels.

Table 8. Results of the analysis of the interaction between training methods and power on hip toss skills

Interaction	F-count	F-table	Sig.	Explanation
Interaction A vs B	7.914	3.17	0.001	There is a interaction

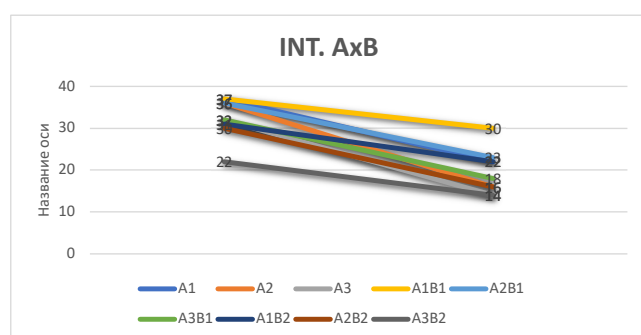
There is a significant interaction between training methods (A) and power levels (B) on the hip toss skills

of FIK UNM students ($F\text{-count} = 7.914$, $F\text{-table} = 3.17$, $p = 0.001$). The $F\text{-count}$ value, which is greater than the $F\text{-table}$ value, and the significance level of less than 0.05 indicate that the effects of training methods cannot be considered independent of athletes' power levels. In other words, the effectiveness of training methods is influenced by power levels, and vice versa, suggesting that these two variables interact in influencing hip toss skill outcomes. To better illustrate the interaction between training methods and power levels on hip toss skills in the Department of Physical Education, Health, and Recreation students, refer to the following figure:

Among the primary groups, the resistance band (A₁) showed significantly better results compared to good morning (A₂) ($MD = 5.000$, $p = 0.007$) and bicep curl (A₃) ($MD = 9.636$, $p < 0.001$). This indicates that resistance band exercises are the most effective method for improving hip toss skills. Good morning exercises also showed a significant advantage over bicep curls ($MD = 4.636$, $p = 0.017$), emphasizing their role in supporting postural stability. In

Table 9. Advanced ANOVA results with tukey test

Hypothesis Groups Compared		Mean Difference (I-J)	Std. Error	Sig.	95 % Confidence Interval		Exp.
(I) Group	(J) Group				Lower Bound	Upper Bound	
A ₁	A ₂	5.000*	1.319	.007	.84	9.16	There Is a Difference
A ₁	A ₃	9.636*	1.319	.000	5.47	13.80	There Is a Difference
A ₂	A ₃	4.636*	1.319	.017	.47	8.80	There Is a Difference
A ₁ B ₁	A ₂ B ₁	6.364*	1.865	.024	.47	12.25	There Is a Difference
A ₁ B ₁	A ₃ B ₁	4.182	1.865	.386	-1.71	10.07	There Is a Difference
A ₂ B ₁	A ₃ B ₁	-2.182	1.865	.961	-8.07	3.71	No Difference
A ₁ B ₂	A ₂ B ₂	-1.818	1.865	.987	-7.71	4.07	No Difference
A ₁ B ₂	A ₃ B ₂	3.091	1.865	.771	-2.80	8.98	No Difference
A ₂ B ₂	A ₃ B ₂	4.909	1.865	.184	-.98	10.80	There Is a Difference

**Fig. 1.** Interaction between resistance band training, bicep curl training, and power levels on hip toss skills

the combination of training methods and high-power levels, resistance band (A₁B₁) demonstrated a significant difference compared to good morning (A₂B₁) (MD = 6.364, $p = 0.024$), but no significant difference compared to bicep curls (A₃B₁) (MD = 4.182, $p = 0.386$). Furthermore, no significant difference was found between good morning (A₂B₁) and bicep curl (A₃B₁) (MD = -2.182, $p = 0.961$), suggesting similar effectiveness of these two methods within the high-power group. In the low-power group, no significant differences were observed between the resistance band (A₁B₂) and good morning (A₂B₂) (MD = -1.818, $p = 0.987$) or bicep curl (A₃B₂) (MD = 3.091, $p = 0.771$). However, good morning exercises (A₂B₂) showed an almost significant advantage over bicep curls (A₃B₂) (MD = 4.909, $p = 0.184$).

Discussion

The research findings in Table 9 indicate that the training methods of resistance band exercises, good morning drills, and bicep curls have a significant impact on improving hip toss skills in wrestlers, with effectiveness varying based on the athletes' initial power levels. Resistance band training proved the most effective, particularly for athletes with high power, by enhancing dynamic strength and muscle flexibility crucial for executing hip toss techniques. The good morning exercise significantly contributed to postural stability and strengthening of the posterior chain, while bicep curls

improved grip strength, which is essential for grappling techniques (Nguyen et al., 2023; Nuzzo et al., 2023; Peres et al., 2023; Ross et al., 2024).

In Table 9, The interaction between resistance band training and high-power levels yielded the best results compared to other combinations. Athletes with high power tend to have more muscular foundational strength, enabling them to effectively utilize the variable resistance provided by resistance bands (Arifin et al., 2024; Kusumawati et al., 2022; Novak et al., 2023). This resistance facilitates intensive training, significantly enhancing dynamic strength and technical skills. The good morning exercise also produced positive results in the high-power group, though its effectiveness was lower than resistance bands. High-power athletes benefited from the postural stability reinforcement provided by the good morning exercise, which supports body control during hip toss techniques (Ross et al., 2024). However, due to the lack of direct contribution to dynamic strength, its results were more limited than resistance band training.

In Table 9, Resistance band training maintained its superiority in the low-power group compared to other methods. The adjustable resistance allows athletes with low power to progressively train their strength without the risk of injury from excessive loads (Gupta et al., 2022; Long et al., 2024; Shadgan et al., 2024). The ability of resistance bands to target multiple muscle groups simultaneously offers a significant advantage in the context of technical skills. The good morning exercise showed moderate results in the low-power group. While effective for strengthening the posterior chain, its limitations in providing comprehensive muscle reinforcement make it less ideal for athletes with low power. The postural stability developed through good morning exercises may not be sufficient to support significant improvements in hip toss skills. Based on these comparisons, resistance band training consistently proved superior across all conditions, whether in high-power or low-power groups. The good morning exercise significantly contributed to postural stability, particularly in the high-power group, while bicep curls were more relevant as a supplementary exercise to support grip strength.

The findings of this study provide valuable insights into the advantages of resistance band training, which was proven to be the most effective method for improving hip toss skills

in both high-power and low-power groups. This advantage aligns with previous research showing that resistance bands offer variable resistance, allowing for better neuromuscular adaptation than traditional training methods (Devi et al., 2022; Woo et al., 2024). Resistance bands also facilitate the dynamic strength development required for explosive movements such as the hip toss (Francino et al., 2022).

This study reinforces evidence that resistance bands are a flexible training tool suitable for athletes across various skill levels. They allow a wide range of motion and adjustable resistance, making them adaptable to the specific needs of each athlete. This adaptability makes resistance bands ideal for dynamic strength development, especially in competitive sports (Long et al., 2024). Additionally, resistance bands support functional strength and balance two critical components in dynamic strength development. This has also been demonstrated in research involving broader populations, including older adults (Davis et al., 2022; Hejazi et al., 2024; Konukman et al., 2022).

The findings of this study align with previous literature highlighting the advantages of resistance bands in enhancing dynamic strength. (Sivaraman et al., 2024) emphasize that resistance bands effectively target core and shoulder muscles, critical for explosive movements such as hip tosses in wrestling. Resistance bands have also been proven to support flexibility and injury prevention, making them an ideal training tool for athletes with varying levels of initial strength (Wang, 2024; Wangi, 2023). The good morning exercise has long been recognized as an effective method for strengthening the posterior chain. Research by (Franco-López et al., 2024) shows that this exercise enhances postural stability, which is crucial for maintaining body balance during dynamic techniques. While this is important for executing hip tosses, its results in improving dynamic strength were lower than resistance band training (Ross et al., 2024).

On the other hand, bicep curls provide significant benefits in improving grip strength, though their contributions to dynamic movements and postural stability are more limited. Bicep curls strengthen the biceps brachii and brachioradialis muscles, which are critical in enhancing grip strength. Ceylan (2023) notes that improved grip strength helps athletes control opponents during grappling techniques. However, the findings of this study suggest that bicep curls are better suited as a complementary exercise in a multidimensional training program.

The implications of this study's findings are significant for designing multidimensional training programs in wrestling. Resistance band training can serve as the core component of such programs, as it substantially improves dynamic strength and flexibility. Coaches can utilize resistance bands to train explosive movements relevant to hip toss techniques, as outlined by (Wang et al., 2023). Studies by (Ross et al., 2024) emphasize the importance of body stability in maintaining balance during hip toss techniques. Incorporating good morning exercises as a complement to resistance bands can effectively strengthen core muscles, supporting stability during dynamic movements.

Bicep curls can be incorporated to enhance grip strength and arm power, which are crucial for grappling techniques and contribute directly to grip performance (Sabillah et al., 2022). This aligns with findings by (Ceylan, 2023), who highlighted that greater grip strength boosts confidence and

control over opponents. Furthermore, research suggests that variations of the bicep curl, such as the reverse grip curl, can increase maximum arm strength, benefiting control during grappling and throwing techniques (Dereshgi, 2023). Different grip positions in these exercises influence muscle activation patterns, allowing for muscle strengthening tailored to the specific demands of combat sports (Coratella et al., 2023). Thus, combining these training methods provides a holistic approach to improving hip toss skills in wrestlers, addressing dynamic strength and sport-specific needs.

Integrating resistance bands, good morning exercises, and bicep curls offers a comprehensive approach to improving hip toss skills. Resistance bands enhance dynamic strength, good morning exercises improve postural stability, and bicep curls strengthen grip, creating a synergy that enhances overall performance. This study demonstrates that this multidimensional approach can be applied across various martial arts disciplines, such as judo and taekwondo, to improve sport-specific technical skills. Training programs incorporating these methods should consider athletes' initial strength levels and individual needs. Athletes with high power may benefit from prioritizing resistance bands and good morning exercises, while those with low power gain the most from resistance band training to build a more muscular foundational strength (Rusmi, 2023). This tailored approach ensures optimal outcomes for athletes across different strength levels and disciplines.

Conclusions

This study demonstrates that the training methods of resistance bands, good morning exercises, and bicep curls significantly impact improving hip toss skills in wrestlers. Resistance bands were the most effective method for enhancing dynamic strength and muscle flexibility, particularly for high-power athletes. The good morning exercise supports postural stability and strengthens the posterior chain, which is essential for maintaining body balance during hip toss techniques. Meanwhile, bicep curls significantly improve grip strength, although their influence on explosive movements and overall body stability is limited. These findings emphasize the importance of a multidimensional training approach in wrestling, where integrating resistance bands, good morning exercises, and bicep curls provide complementary benefits to enhance technical skills. The study also highlights that athletes' initial strength levels affect their response to training methods, with resistance bands showing flexibility for use by both high- and low-power athletes.

Coaches and athletes are encouraged to prioritize resistance bands as a primary training method in programs designed to enhance dynamic strength and muscle flexibility, particularly for explosive movements such as hip tosses. Resistance bands can be effectively combined with good morning exercises to improve postural stability and strengthen the posterior chain. At the same time, bicep curls should be included to boost grip strength, especially for grappling techniques. Training intensity and duration should be tailored to the athlete's initial strength levels to maximize results. For future research, it is essential to explore the effectiveness of these training methods in more diverse populations, including professional athletes, adolescents, and individuals

with specific conditions such as injuries. Studies of longer duration are also recommended to evaluate the long-term impact of these training methods. Additionally, incorporating advanced technologies like motion capture or wearable sensors could facilitate deeper biomechanical analyses of hip toss techniques, providing further insights into training effectiveness. Training centers should consider integrating a multidimensional approach into their wrestling training curriculums, combining various methods that address the specific needs of their athletes. Furthermore, additional training for coaches is essential to effectively implement resistance bands, good morning exercises, and bicep curls, leveraging evidence-based practices. By adopting these strategies, wrestling programs can significantly improve athletes' technical skills in executing hip toss techniques, leading to enhanced competition performance.

Conflict of Interest

The authors declare that they have no conflicts interests.

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Встановлення взаємозв'язку між тренувальними методами та рівнями показників потужності у спортивній боротьбі: Факторний дизайн 2×3 щодо навичок виконання кидка через стегно

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

Реферат. Стаття: 11 с., 9 табл., 1 рис., 45 джерел.

Мета дослідження. Це дослідження мало на меті визначити вплив виконання комплексу вправ з еспандером, тренувань “Good morning” (нахили корпусу зі штангою на спині) та згинання рук на біцепс щодо покращення техніки кидка через стегно у спортсменів-борців, враховуючи їхній початковий рівень показників потужності.

Матеріали та методи. У цьому дослідженні застосовано факторний дизайн 2×3 із залученням 66 студентів чоловічої статі, яких було згруповано за рівнем показників потужності (високий і низький) та методами тренування. Тренування проводилися протягом шести тижнів із частотою трьох щотижневих занять. Параметри, що вимірювалися, включали в себе вдосконалення навичок техніки кидка через стегно, в тому числі показників сили, стабільності та швидкості виконання. Аналіз даних проведено із застосуванням методу дисперсійного аналізу (ANOVA) та тесту Тьюкі з метою оцінки достовірних відмінностей між групами.

Результати. Результати показали суттєвий основний вплив фактору методу тренування (А) на навички виконання кидка через стегно ($F = 5,413$; $p = 0,007$), демонструючи, що варіації в методах тренування призвели до помітних відмінностей у показниках володіння цими навичками. Другий основний ефект, рівень потужності (В), виявив більш істотний вплив ($F = 99,426$; $p = 0,000$), що свідчить про ключову роль вихідного рівня розвитку потужності спортсменів у визначенні результативності виконання кидка через стегно. Щодо ефекту взаємодії, встановлено значний взаємозв'язок між методами тренування та рівнями показників потужності ($F = 7,914$; $p = 0,001$).

Висновки. За результатами цього дослідження можна стверджувати, що вправи з еспандером є найефективнішим методом підвищення динамічної сили та гнучкості для спортсменів з високими показниками потужності, необхідними для виконання техніки кидків через стегно. Вправа “Good morning” забезпечує ефективну підтримку позу постуральної стабільності, а згинання рук на біцепс сприяє зміцненню сили хвату. Багатовимірний підхід, що поєднує вправи з еспандером, нахили зі штангою на спині та згинання рук на біцепс, надає додаткові переваги щодо вдосконалення навичок техніки виконання кидка через стегно у спортивній боротьбі. Отримані дані можуть слугувати основою для розроблення тренерами науково обґрунтованих тренувальних програм з урахуванням конкретних потреб спортсменів.

Ключові слова: еспандер, вправа “Good morning”, згинання рук на біцепс, кидок через стегно, спортивна боротьба.

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Engaging in High-Intensity Interval Training is More Effective than Moderate-Intensity Interval Training in Improving Aerobic Capacity and Body Composition in Students

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Abstract

Objectives. This study aimed to prove the difference in the effects of high-intensity interval training (HIIT) and moderate-intensity continuous training (MICT) on increasing aerobic capacity and improving body composition.

Materials and methods. This study examined the effects of two different training methods – moderate-intensity continuous training (MICT) and high-intensity interval training (HIIT) on aerobic capacity and body composition among 30 university students aged 19-22, using a pretest-posttest control group design. Participants were randomly assigned to either the MICT, HIIT, or Control (no training) groups and trained three times a week for four weeks. Aerobic capacity was measured with the 12-Minute Cooper Test, and body composition was assessed using the TANITA BC-545N. Data analysis included descriptive statistics, normality tests and ANOVA tests to evaluate group differences.

Results. The results indicate that HIIT yields greater enhancements in aerobic capacity and body composition (e.g., reduced body fat and increased fat-free mass) compared to MICT, while the CTRL group appears to demonstrate minimal changes. Additionally, no significant differences in BMI were observed between the three groups ($p \geq 0.05$).

Conclusions. These findings suggest that HIIT may serve as an effective training approach for individuals seeking optimal fitness gains and improved body composition with shorter exercise durations.

Keyword: aerobic capacity, body composition, healthy lifestyle, exercise, physical fitness.

Introduction

Low levels of physical activity among college students are often caused by a variety of factors, such as academic demands, lifestyle, and lack of support or facilities. Lack of physical activity can result in decreased cardiovascular health, which is at risk of increasing heart disease and hypertension in the future (Wilhite et al., 2023). Low physical activity makes the cardiovascular system and heart not function

properly, potentially causing long-term health problems. In addition, low physical activity reduces calorie burning; If accompanied by an unhealthy diet, this can contribute to weight gain or even obesity (Ashadi et al., 2024). Obesity at a young age can have adverse health effects, including an increased risk of type 2 diabetes, hypertension, and other chronic diseases (Binsaeed et al., 2023).

Barriers to training time management are often the main reason students don't exercise regularly. Previous research indicates that moderate intensity continuous training (MICT) is effective in burning body fat, because this method keeps the body in the fat burning zone for a long time (Muhammad et al., 2024). However, moderate intensity continuous training also has some drawbacks that

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can affect its effectiveness in burning fat and providing long-term fitness benefits (Paria et al., 2024). Moderate intensity continuous training takes longer to burn a significant amount of calories or fat compared to high-intensity workouts such as high intensity interval training (Yin et al., 2023). This becomes a challenge for individuals with busy schedules, as these exercises take longer to achieve similar results. Moderate intensity continuous training also produces a low excess post-exercise oxygen consumption (EPOC), meaning that after the workout session is over, the body does not burn a large amount of additional calories, so the fat burning effect is reduced faster compared to high-intensity exercise (Isanejad et al., 2023).

Moderate-intensity continuous training involves activities that are performed at a consistent pace or intensity over a long period of time, such as running or cycling at a moderate pace (Namboonlue et al., 2024). This routine tends to feel monotonous and can reduce long-term motivation, so many people find it difficult to stay consistent in practice (Gerosa-Neto et al., 2020). In addition, the body can quickly adapt to the constant intensity of moderate exercise, so the benefits of moderate intensity continuous training in terms of calorie burning and fitness improvement can decrease over time (Choudhary & Dubey, 2024). Once the body gets used to it, those benefits may diminish unless the duration or intensity of the exercise is increased, which requires additional time and effort (Rolid et al., 2020). Moderate intensity continuous training does not significantly stimulate muscle growth because it puts more emphasis on duration than strength or energy bursts. This type of exercise is less optimal for those who want to improve body composition through increased muscle mass, since it does not provide a sufficiently intense load or stimulation to the muscles (Lu et al., 2022).

High intensity interval training (HIIT) is more able to stimulate metabolic hormone responses such as epinephrine, which is more effective at burning fat compared to moderate intensity continuous training (Khalafi et al., 2020). In moderate intensity continuous training, the release of these hormones is less, so the impact on fat metabolism is not as strong as high-intensity exercise (Aparecido et al., 2022). Moderate intensity continuous training is generally successful in improving cardiovascular fitness, but it is less effective at increasing strength, explosiveness, or flexibility (Yu et al., 2022). For individuals looking to achieve a variety of fitness goals, moderate intensity continuous training is less flexible compared to exercises that offer variety in intensity and type (Ruiz-Urbe et al., 2024).

Individuals with limited time to train in order to improve aerobic capacity and improve body composition significantly, moderate intensity continuous training may not be the best option (Youssef et al., 2022). Therefore, The novelty of this study to proves that high intensity interval training offers some important new elements compared to moderate intensity continuous training, especially in terms of its effectiveness to increase aerobic capacity and improve body composition in college students who have a less active lifestyle. These new elements include intensity, movement variation, EPOC, after-burn effects, as well as the long-term impact of HIIT that cannot be achieved with the moderate intensity continuous training intervention (Khodadadi et al., 2023). High intensity interval training can lead to more significant improvements in aerobic capacity and body composition

compared to moderate intensity continuous training (Casaña et al., 2022). High intensity interval training has been shown to be more effective in increasing VO_2 max, which is the body's ability to utilize oxygen optimally, as it encourages the cardiovascular system to work harder and adapt faster (Hu et al., 2021). In addition, the post-workout calorie burn (EPOC) effect on HIIT is also higher, so the body continues to burn more fat even after the workout session is over (Martínez-Rodríguez et al., 2021). Therefore, HIIT is an efficient option to improve cardiovascular health, burn body fat, and improve overall body composition (Gawel et al., 2024).

This study aims to prove that high intensity interval training (HIIT) is superior to moderate intensity continuous training (MICT) in increasing aerobic capacity and improving body composition. This research contributes to various aspects of fitness and health that are very important for the global community, especially in efforts to promote healthy lifestyles, time efficiency, and long-term health management. The findings proving that HIIT is more effective than MICT in improving aerobic capacity, body composition, and overall health are invaluable to the international community. In addition, the study not only provides solutions to public health problems, but also presents valuable information for individuals looking for more efficient ways to exercise.

Material and Methods

Study design

This study involved a total of 30 young students who were participants. The inclusion criteria were individuals aged 19-22 years, body mass index (BMI) 15-25 kg/m^2 , normal systolic and diastolic blood pressure 120-110/90-80 mmHg, resting heart rate (RHR) 70-90 bpm, oxygen saturation 97-100 %, and body temperature 36.5-37.2 °C. Subjects were verified to have no history of smoking, non-alcoholic consumption, non-hypertension, and non-diabetes. In addition, the participants did not have any disease with personalised therapy through specific medical interventions. The study involved two independent variables: moderate-intensity continuous training (MICT) and high-intensity interval training (HIIT), as well as two dependent variables: aerobic capacity and body composition. Following informed consent, subjects underwent health screenings and pretests for aerobic capacity and body composition and were then randomly assigned into three groups: the MICT group, the HIIT group, and a control group with no training. The training program was implemented over a 4-week period with a frequency of three sessions per week (Table 1).

Data Collection

The research process was carried out with the following steps: first, the research subject fills out an approval form. After agreeing to participate, all participants underwent a health check, including pulse and blood pressure measurements, as well as a pretest for aerobic capacity and body composition. The subjects were then randomly divided into three groups: A, B, and C. Group A underwent moderate-intensity continuous training (MICT), group B did high-intensity interval training (HIIT), while group C did not exercise. The exercise program lasts for 4 weeks with

Table 1. HIIT and MICT training program

Groups	MICT's Group (Group A, n = 10)	HIIT's Group (Group B, n = 10)	Control's Group (Group C, n = 10)
Intensity week 1	1. 70 % MAS 40 Min	15 s @100 % MAS : 15 s 70 % MAS X 10 Reps (3 Min Rest BS) X 4 Set	No Training
Intensity week 2	2. 70 % MAS 50 Min	15 s @107 % MAS : 15 s 70 % MAS X 10 Reps (3 Min Rest BS) X 4 Set	No Training
Intensity week 3	3. 70 % MAS 50 Min	16 s @114 % MAS : 15 s 70 % MAS X 10 Reps (3 Min Rest BS) X 4 Set	No Training
Intensity week 4	4. 70 % MAS 60 Min	17 s @120 % MAS : 15 s 70 % MAS X 10 Reps (3 Min Rest BS) X 4 Set	No Training

a frequency of 3 times a week. After the 4-week intervention period, it was followed by a posttest to re-measure the subject's aerobic capacity and body composition. Aerobic capacity was measured with the 12-Minute Cooper Test, and body composition was assessed using the TANITA BC-545N.

Statistical Analysis

Descriptive statistical analysis was applied to assess the mean and standard deviation. Shapiro–Wilk and Levene's test were applied to assess the normality and homogeneity of the data. Data that is normally distributed and has homogeneous variance is assessed using the one-way ANOVA test and followed by the LSD post-hoc test to assess differences between groups. Meanwhile, paired sample t-test was applied to assess baseline (pre) and 4 week (post) data in each group for all research variables. All statistical analyzes were implemented with SPSS Statistics for Windows version 21.0. Data was declared to have a significant difference if $p < 0.05$.

Results

The results of the analysis of assessment of aerobic capacity and body composition at baseline (pre) and 4 weeks (post) in each group are presented in Figure 1-4.

The results of the aerobic capacity analysis in Figure 1 show a significant increase after intervention for 4 weeks (post) compared to baseline (pre) at MICT ($p = 0.006$;

ES: 0.859; 95 % CI: -7.01, -1.62), and at HIIT ($p = 0.683$; ES: 0.112; 95 % CI: -2.11, 3.07), while there was no significant difference at CTRL observed ($p = 0.000$; ES: 1.086; 95 % CI: -8.89, -6.48).

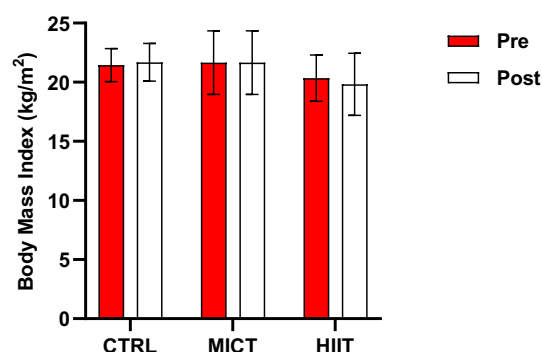


Fig. 2. Assessment of body mass index baseline (pre) and 4 week (post) in each group. *Significant at baseline (pre) $p \leq 0.05$. Data are presented as mean $\pm$ SD. The p-value was obtained from the paired sample t-test assessment

The results of the body mass index analysis in Figure 2 do not show any significant changes observed between baseline (pre) and 4 weeks (post) intervention at CTRL ($p = 0.156$; ES: 0.163; 95 % CI: -0.60, 0.11), at MICT ($p = 0.990$; ES: 0.001; 95 % CI: -0.34, 0.34), and at HIIT ($p = 0.167$; ES: 0.219; 95 % CI: -0.26, 1.27).

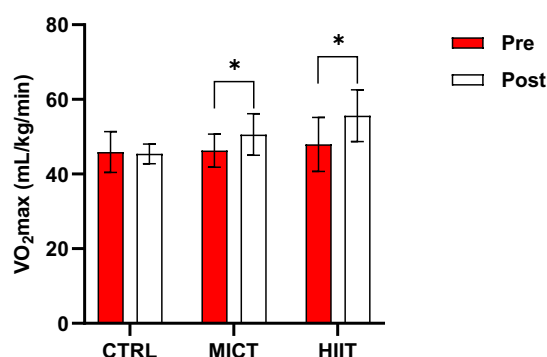


Fig. 1. Assessment of aerobic capacity baseline (pre) and 4 week (post) in each group. *Significant at baseline (pre) $p \leq 0.05$. Data are presented as mean $\pm$ SD. The p-value was obtained from the paired sample t-test assessment

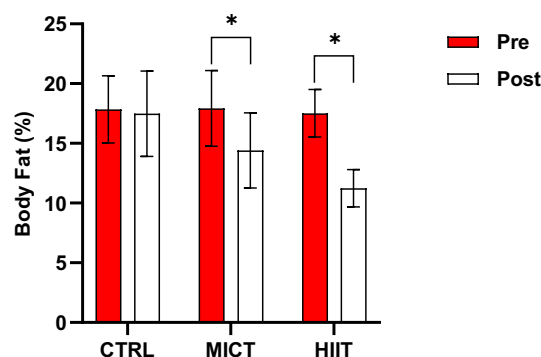


Fig. 3. Assessment of body fat baseline (pre) and 4 week (post) in each group. *Significant at baseline (pre) $p \leq 0.05$. Data are presented as mean $\pm$ SD. The p-value was obtained from the paired sample t-test assessment

Table 2. Assessment of aerobic capacity and body composition in all participants

Parameters	CTRL, n = 10	MICT, n = 10	HIIT, n = 10	p-value
Pre-VO ₂ max (mL·kg ⁻¹ ·min ⁻¹)	45.89 ± 5.48	46.27 ± 4.44	47.94 ± 7.22	0.709
Post-VO ₂ max (mL·kg ⁻¹ ·min ⁻¹)	45.41 ± 2.62	50.59 ± 5.55*	55.63 ± 6.92*†	0.001
Δ-VO ₂ max (mL·kg ⁻¹ ·min ⁻¹)	-0.49 ± 3.62	4.32 ± 3.77*	7.69 ± 1.69*†	0.000
Pre-BMI (kg/m ²)	21.44 ± 1.39	21.65 ± 2.69	20.34 ± 1.96	0.333
Post-BMI (kg/m ²)	21.69 ± 1.59	21.65 ± 2.69	19.83 ± 2.62	0.151
Δ-BMI (kg/m ²)	0.25 ± 0.50	0.00 ± 0.47	-0.51 ± 1.07	0.082
Pre-BF (kg)	17.85 ± 2.81	17.93 ± 3.17	17.52 ± 1.99	0.938
Post-BF (kg)	17.48 ± 3.57	14.40 ± 3.15*	11.24 ± 1.57*†	0.000
Δ-BF (kg)	-0.37 ± 1.61	-3.53 ± 0.96*	-6.28 ± 1.91*†	0.000
Pre-FFM (kg)	50.18 ± 3.41	52.25 ± 3.49	48.66 ± 4.57	0.132
Post-FFM (kg)	50.37 ± 3.55	54.87 ± 3.89*	54.04 ± 3.78*	0.028
Δ-FFM (kg)	0.19 ± 0.61	2.62 ± 1.38*	5.39 ± 1.67*†	0.000

* Significant at CTRL $p \leq 0.05$. †Significant at MICT $p \leq 0.05$. Data are presented as mean ± SD. The p-value was obtained from the one-way ANOVA followed by LSD post-hoc test

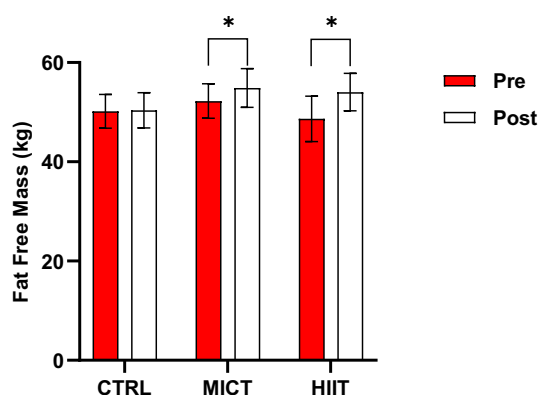


Fig. 4. Assessment of body fat baseline (pre) and 4 week (post) in each group. *Significant at baseline (pre) $p \leq 0.05$. Data are presented as mean ± SD. The p-value was obtained from the paired sample t-test assessment

The results of body fat analysis in Figure 3 show a significant reduction after 4 weeks of intervention (post) compared to baseline (pre) at MICT ($p = 0.000$; ES: 1.118; 95 % CI: 2.84, 4.22), and at HIIT ($p = 0.000$; ES: 3.501; 95 % CI: 4.92, 7.64), while at CTRL no significant differences were observed ($p = 0.487$; ES: 0.115; 95 % CI: -0.79, 1.53).

The results of the free fat mass analysis in Figure 4 show a significant increase after 4 weeks of intervention (post) compared to baseline (pre) at MICT ($p = 0.000$; ES: 0.709; 95 % CI: -3.61, -1.64), and at HIIT ($p = 0.000$; ES: 1.284; 95 % CI: -6.58, -4.19), whereas at CTRL no significant difference was observed ($p = 0.487$; ES: 0.115; 95 % CI: -0.79, 1.53). Assessment of aerobic capacity and body composition in all participants was presented in Table 2.

Discussion

High-intensity interval training (HIIT) and moderate-intensity continuous training (MICT) are two popular workout methods aimed at enhancing aerobic capacity and improving body composition, particularly in reducing

body fat and increasing muscle mass. Although both interventions are effective, research findings indicate that HIIT is significantly more efficient than MICT in achieving these outcomes. The body burns more calories at higher intensities during HIIT interventions compared to moderate continuous exercise. This is particularly crucial for students with limited time, as they require effective and efficient workouts to quickly enhance aerobic capacity and burn fat (Domaradzki et al., 2023).

High intensity interval training exercise interventions resulted in faster improvements in heart and lung efficiency compared to moderate intensity continuous training (Marcotte-Chénard et al., 2021). High-intensity training increases heart volume per beat (stroke volume) and lung capacity to deliver oxygen to the muscles, which accelerates the body's cardiovascular adaptation and contributes to a significant increase in VO₂max (Russomando et al., 2020). The combination of periods of high intensity with periods of rest allows the body to function at a higher capacity in a short period of time, resulting in an increase in better aerobic efficiency (Guo et al., 2023). Meanwhile, while MICT is effective for maintaining fitness, its increase in aerobic capacity tends to be slower and less significant due to its stable and moderate intensity during exercise (Scoubeau et al., 2022).

One of the factors that makes high intensity interval training more efficient in increasing aerobic capacity is due to the excess post-exercise oxygen consumption (EPOC) effect. After a HIIT session, the body still burns more oxygen and calories for the recovery process (Domaradzki et al., 2022). This excess post-exercise oxygen consumption (EPOC) contributes to an increase in the body's aerobic efficiency, which does not occur in moderate intensity continuous training (Moro et al., 2020). Moderate intensity continuous training generally does not produce such an effect, so the body's recovery does not contribute to an increase in aerobic capacity in the long term (Murawska-Ciałowicz et al., 2020).

The composition of the body consists of fat mass and fat-free mass, which includes muscle. High-Intensity Interval Training (HIIT) improves the efficiency of the body's energy use, both during exercise and afterwards (Kozłenia et al.,

2024). High-intensity interval training promotes significant calorie burning, including calories from fat, both during training sessions and during recovery through the EPOC effect (Hooshmand Moghadam et al., 2021). This process is more effective in reducing body fat, including visceral fat that surrounds internal organs and is associated with the risk of metabolic diseases (Fang et al., 2021).

Increasing muscle mass through HIIT interventions has been shown to be more effective compared to MICT exercises (Unterberger et al., 2022). HIIT involves exercises that use large muscle groups and prioritize muscle strength, such as squats, jumping, and sprints. This movement not only increases aerobic capacity but also stimulates muscle growth. In contrast, MICT focuses more on cardiovascular endurance, while HIIT contributes to increased strength and muscle mass, which can further speed up the body's metabolism (Alarcón-Gómez, Chulvi-Medrano, et al., 2021). With higher muscle mass, the body can burn more calories even when at rest (Alarcón-Gómez, Calatayud, et al., 2021).

The advantages of HIIT in reducing subcutaneous fat and belly fat have proven to be significantly more effective. Research shows that HIIT is more successful in reducing subcutaneous body fat, which is the fat located under the skin, as well as belly fat, which is more difficult to remove (Atakan et al., 2021). On the other hand, although MICT also helps in fat reduction, this method does not specifically target belly fat and does not provide results as fast as HIIT. One of the main advantages of HIIT workouts is their shorter duration, which is about 20 to 30 minutes, but still gives comparable or even better results compared to longer workouts such as MICT (30-60 minutes) (Duarte Martins et al., 2024). HIIT offers higher effectiveness in a more efficient time, making it an attractive option for those with busy schedules, especially housewives or workers with limited time to exercise (Jiménez-Maldonado et al., 2020). HIIT programs can improve adherence to exercise routines because of their shorter duration and more dynamic nature, making many individuals feel more motivated to practice HIIT consistently (Zhang et al., 2022). In contrast to MICT which tends to be monotonous and requires more endurance, HIIT is more appealing to many people, thus helping to improve long-term compliance (Wang et al., 2020).

Previous research indicates that HIIT, performed only 2-3 times a week, can increase aerobic capacity by 25-30% in a short period of time (about 2-3 weeks), while MICT requires more time and frequency of exercise to achieve equivalent results (Songsorn et al., 2022). A meta-analysis of various studies showed that HIIT was more effective in reducing body fat compared to MICT, where the decrease in visceral fat and the increase in muscle mass were more significant (Rolid et al., 2020). Individuals who underwent a HIIT program experienced an increase in VO₂ max and a greater decrease in body fat percentage compared to those who followed a MICT program of the same duration (Flensted-Jensen et al., 2021).

HIIT is much more effective than MICT in increasing aerobic capacity and improving body composition. One of the main advantages of HIIT is its ability to accelerate cardiovascular improvement and boost metabolism in less time (Lu et al., 2022). HIIT is also more efficient at reducing body fat, including belly fat, as well as stimulating the growth of muscle mass. With shorter durations and higher workout

variation, HIIT is also more acceptable and appealing to those who have limited time or who prefer a more dynamic workout (Legaard et al., 2022). Therefore, HIIT is a more efficient and effective option for achieving fitness goals, especially when it comes to increasing aerobic capacity and improving body composition (Ballesta-García et al., 2020).

The research indicates that HIIT is more effective than MICT for enhancing aerobic capacity and body composition, but there are some limitations to consider. These limitations include the impact of overall diet and lifestyle, which can influence exercise outcomes. Without careful monitoring of calorie intake, sleep quality, and stress levels, the results of HIIT or MICT may not solely reflect the effects of exercise. The study focused exclusively on sports students who were already physically active outside of the provided interventions. Conversely, data suggests that non-sports students might be more susceptible to obesity due to various lifestyle factors, stress, and time constraints. To obtain more reliable and generalizable results, additional research with larger sample sizes and longer intervention periods is required.

Conclusions

The conclusions of this study showed that the group that followed the high-intensity interval training intervention proved to be more effective compared to continuous moderate-intensity exercise in improving aerobic capacity and improving body composition. These findings are relevant for a wide range of health and fitness programs, especially for less active individuals. Practically, the results of this research can be used to design a more efficient, accessible, and flexible fitness program for people who have limited time. With appropriate adjustments, these results have the potential to have a positive impact on the physical and mental health of the community.

Conflict of Interest

The authors declare that they have no conflict of interest.

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Виконання високоінтенсивних інтервальних тренувань є ефективнішим за проведення інтервальних тренувань помірної інтенсивності з точки зору покращення аеробної здатності та композиції тіла у студентів

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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 табл., 4 рис., 47 джерела.

Мета дослідження. Мета цього дослідження полягала в доведенні різниці щодо впливу високоінтенсивного інтервального тренування (ВІТ) та безперервного виконання тренування помірної інтенсивності (БТПІ) на підвищення показників аеробної здатності та поліпшення компонентного складу тіла.

Матеріали та методи. У цьому дослідженні вивчався вплив двох різних методик тренувань — безперервного тренування помірної інтенсивності (БТПІ) та високоінтенсивного інтервального тренування (ВІТ) на показники аеробної здатності та композиції тіла у 30 студентів університету віком 19-22 років, використовуючи модель контрольної групи з претест-посттестовим дизайном. Учасників було рандомізовано до груп, що займалися БТПІ, ВІТ або контрольної групи (без виконання тренувань). Тренування проводились тричі на тиждень протягом чотирьох тижнів. Вимірювання аеробної здатності проводилось за допомогою 12-хвилинного тесту Купера, а визначення компонентного складу тіла

здійснювалось із використанням пристрою TANITA BC-545N. Аналіз даних включав описові методи статистики, тести на нормальність розподілу та тести дисперсійного аналізу (ANOVA) з метою оцінки відмінностей між групами.

Результати. Результати вказують на те, що застосування ВІІТ призводить до значнішого покращення показників аеробної здатності та компонентного складу тіла (наприклад, зниження вмісту жиру в організмі та підвищення безжирової маси тіла) порівняно з БТІІ, тоді як контрольна група демонструє мінімальні зміни. Крім того, між трьома групами не спостерігалось суттєвих відмінностей в показниках ІМТ ($p \geq 0,05$).

Висновки. Отримані дані свідчать про доцільність застосування ВІІТ як ефективного тренувального підходу для осіб, які прагнуть досягти оптимального рівня фізичної підготовленості та покращити композицію тіла за допомогою коротших за тривалістю тренувань.

Ключові слова: аеробна здатність, композиція тіла, здоровий спосіб життя, фізичні вправи, фізична підготовленість.

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Assessing the Effects of Sports Disciplines on Body Composition and Bone Health: A Focus on Yoga, Weightlifting, and Long-Distance Running

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Abstract

Background. Understanding how different sports influence bone health and body composition is key to improving athletic performance and overall well-being. Weightlifting, yoga, and long-distance running each have unique impacts on the body. This study offers insights into how specific sports disciplines shape bone health and body composition, providing valuable guidance for enhancing fitness and health recommendations.

Objectives. The study aimed to assess the effects of weightlifting, yoga, and long-distance running on body composition and bone mineral density, highlighting how these activities significantly influence both factors.

Materials and methods. A random sampling method was used to select ninety (N = 90) interuniversity athletes. The sample consisted of long-distance runners (n = 30), weightlifting athletes (n = 30), and yoga practitioners (n = 30). Bone mineral density was measured using the Achilles EXP II (Part 1) Bone Mineral Density Analyzer, while body composition was assessed with the GS6.5B Body Building Weight Test System (Version 1.0).

Results. Significant differences were observed among the groups in bone mineral density $F_{(2, 87)} = 15.95, p = .000$, body fat percentage $F_{(2, 87)} = 26.15, p = .000$, and skeletal muscle mass $F_{(2, 87)} = 23.30, p = .000$. A post-hoc LSD test showed that weightlifters had the highest bone mineral density and skeletal muscle mass, whereas long-distance runners demonstrated the lowest body fat percentage among the groups.

Conclusions. The study revealed substantial differences in skeletal muscle mass, body fat percentage, and bone mineral density among weightlifters, yoga practitioners, and long-distance runners. These findings highlight the distinct physiological adaptations associated with each sport, emphasizing the need for customized training and health strategies to optimize performance and health outcomes across different athletic disciplines.

Keywords: body composition, bone density, muscle mass, endurance runner, yoga practitioner, weightlifting.

Introduction

Exercise is considered a protective factor that lowers the risk of osteoporosis; however, not all physical activities have an equal effect on bone health. Non-weight-bearing sports may have a neutral or even negative impact (Bellver et al., 2019), whereas weight-bearing exercises are well-documented to promote long-term bone health (Boreham & McKay, 2011; Karlsson & Rosengren, 2012). The development of bone during childhood and adolescence plays a crucial role in determining peak bone mass and the future risk of

osteoporosis and fragility fractures in later life (Baxter-Jones et al., 2011).

Athletes in endurance sports like running or non-weight-bearing activities such as biking and swimming often have lower bone mineral density compared to those in ball or power sports (Schofield & Hecht, 2012), which require strength and power to perform game-related skills effectively (Rahman & Sharma, 2023). In some cases, their bone density is even lower than that of their sedentary peers (Fredericson et al., 2005; Fredericson et al., 2007; Nagle & Brooks, 2011). Low bone mineral density increases the risk of stress and fragility fractures in competitive athletes and later in life (Kelsey et al., 2007). Since adequate bone mineral density is linked to both long-term health and

injury prevention—especially in high-impact sports like running and weightlifting—maintaining bone health is critical (Turner & Robling, 2003). Exercises involving multidirectional motions and high-impact forces, such as gymnastics and team sports, are associated with stronger bones than low-impact exercises (Sale & Elliott-Sale, 2019).

Maintaining optimal body composition and bone health is essential for overall health and athletic performance. These physical traits can be influenced differently by various sports, and it is crucial for athletes and healthcare professionals to understand these differences (Goolsby & Boniquit, 2017; Reza et al., 2024). Endurance sports like long-distance running and cycling, due to their high energy demands, often produce a leaner physique, while strength-based sports like weightlifting tend to increase muscle mass and result in a more muscular appearance (Kraemer et al., 1999). The physiological demands of each sport play a significant role in shaping athletes' body composition and bone health (Carbuhn et al., 2010). Weightlifting, for example, promotes skeletal muscle mass and improves bone mineral density by applying high-intensity resistance that stimulates bone formation (Hong & Kim, 2018).

Yogic practices have shown potential in enhancing physiological and physical metrics, which are essential for unlocking the body's full potential and improving sports performance (Pramanik et al., 2024). By integrating weight-bearing postures with isometric exercises, yoga not only supports bone mineral density but also aids in muscle maintenance, providing these benefits in a gentler, less strenuous manner (Ross & Thomas, 2010). Long-distance running, with its consistent aerobic activity, generally leads to a leaner body composition and lower body fat (Willis et al., 2012). However, its impact on bone health can vary depending on factors like exercise intensity and duration. Long-term participation in endurance sports, such as long-distance running or cycling, may be associated with lower peak bone density (Tenforde & Fredericson, 2011; Barrack et al., 2010).

Understanding how these factors influence bone mineral density and body composition is vital for improving both athletic performance and long-term health. Evaluating the effects of different exercise regimens on bone mineral density is essential in determining which activities provide the most health benefits. The purpose of this study is to offer evidence-based recommendations to motivate individuals to engage in exercise that optimizes both bone health and body composition.

Materials and Methods

Study Participants

In this study, ninety (N = 90) male university-level participants from Punjabi University, Patiala, India, were selected using a random sampling technique. The participants included (n = 30) weightlifters, (n = 30) long-distance runners, and (n = 30) yoga practitioners, all aged between 18 and 25 years and having competed in interuniversity-level competitions in their respective sports. Long-distance runners were defined as those participating in events of 3,000 meters or more. The subjects were recruited from interuniversity camps, ensuring they were actively preparing for upcoming competitions.

The research scholar explained the objectives and procedures of the study, and after obtaining informed consent, the athletes voluntarily participated. All subjects were healthy and free of musculoskeletal problems, with those having medical conditions excluded from the study.

Table 1. The anthropometric data (M $\pm$ SD) of the subjects

Variables	Weight Lifters	Long Distance Runners	Yoga Practitioners
Age (yrs)	19.67 $\pm$ 1.88	20.13 $\pm$ 1.99	23.33 $\pm$ 1.53
Height (cm)	173.12 $\pm$ 9.71	172.51 $\pm$ 5.61	175.00 $\pm$ 6.40
Weight (kg)	67.40 $\pm$ 3.78	58.73 $\pm$ 4.48	63.43 $\pm$ 5.01
BMI (kg/m ²)	22.85 $\pm$ 2.62	20.07 $\pm$ 0.829	20.74 $\pm$ 2.24

Test Procedure

To assess the participants' lean body mass and body fat percentage, the Body Composition Analyzer GS6.5B Body Building Weight Test System (Version 1.0) was used. Bone mineral density (stiffness index) was measured using the Achilles EXP II (Part 1). All tests were conducted in the Physiology Lab of the Department of Physical Education at Punjabi University, Patiala, India. Prior to testing, participants' queries were addressed, and the procedure was thoroughly explained. A certified lab technician was responsible for recording all measurements. For the purposes of the study, skeletal muscle mass (kg), body fat percentage (%), and bone mineral density (stiffness index) were measured and compared among the groups.

Body Composition Analysis

Participants were instructed to remove heavy clothing and accessories and were informed in advance to refrain from eating for at least two hours before the test to ensure accurate measurements (Kyle et al., 2004a). The test administrator guided participants to stand barefoot on the electrode platform and grip the electrode rods with both hands, ensuring full contact between their feet and the electrodes (Sergi et al., 2017). The GS6.5B was calibrated before each session to ensure precision. This system uses bioelectrical impedance analysis (BIA) to measure body composition parameters such as body fat percentage and lean body mass (Kyle et al., 2004b; Mialich et al., 2014).

Bone Mineral Density Analysis

Participants were instructed to remove their shoes and socks. After getting into a comfortable position, they were asked to place their feet between the membranes for the heel scan (Lu et al., 2022; Li et al., 2019). The measurements were performed with the participant seated and one foot placed on the footplate (Weerasinghe et al., 2020). The device sends ultrasonic waves through the heel, and bone mineral density is determined by measuring how much these waves attenuate (Bi et al., 2023). The Achilles EXP II combines speed of sound (SOS) and broadband ultrasound attenuation (BUA) readings to create a clinical metric known as the Stiffness Index, which represents the ultrasound results (Gonnelli et al., 2002; Moayyeri et al., 2012).

Statistical Analysis

The data was analyzed using IBM SPSS software (version 29). Descriptive statistics and one-way ANOVA were employed to fulfil the study's objectives, followed by a post hoc LSD test to identify significant differences. The Shapiro-Wilk test confirmed that the data followed a normal distribution, while Levene's test verified the equality of variances. A significance level of 0.05 was set for all analyses.

Results

A one-way ANOVA (Table 3) revealed significant differences in bone mineral density $F_{(2, 87)} = 15.95$, $p = .000$, body fat percentage $F_{(2, 87)} = 26.15$, $p = .000$, and skeletal muscle mass $F_{(2, 87)} = 23.30$, $p = .000$ among weight lifters, long-distance runners, and yoga practitioners. These results indicate that the type of physical activity significantly influences these physiological parameters.

Table 2. Descriptive statistics of the variables

Parameters	Groups	n	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Bone Mineral Density	Weight Lifters	30	110.40	6.59	1.20	98	118
	Long Distance Runners	30	105.00	5.19	0.95	90	115
	Yoga Practitioners	30	101.77	6.07	1.11	85	117
Body Fat %	Weight Lifters	30	16.69	2.09	0.38	14	20
	Long Distance Runners	30	15.02	1.93	0.35	11	18
	Yoga Practitioners	30	18.39	1.28	0.23	14	20
Skeletal Muscle Mass	Weight Lifters	30	30.78	1.53	0.28	29	34
	Long Distance Runners	30	26.82	2.41	0.44	22	31
	Yoga Practitioners	30	28.46	2.69	0.49	24	33

Table 3. One-way ANOVA of selected parameters of weight lifters, long-distance runners and Yoga practitioners

Variables	Groups	Sum of Squares	df	Mean Square	F-ratio	p-value
Bone Mineral Density	Between Groups	1141.489	2	570.744	15.953	.000
	Within Groups	3112.567	87	35.777		
Body Fat %	Between Groups	170.092	2	85.046	26.145	.000
	Within Groups	283.004	87	3.253		
Skeletal Muscle Mass	Between Groups	238.311	2	119.155	23.296	.000
	Within Groups	445.000	87	5.115		

* Significant at 0.05 level

Table 4. Post-hoc (LSD) test

Parameters	Groups	Groups	Mean Difference	Std. Error	Sig. Level
Bone Mineral Density	Weight Lifters	Long Distance Runners	5.400*	1.544	.001
		Yoga Practitioners	8.633*	1.544	.000
	Long-Distance Runners	Weight Lifters	-5.400*	1.544	.001
		Yoga Practitioners	3.233*	1.544	.039
	Yoga Practitioners	Weight Lifters	-8.633*	1.544	.000
		Long-Distance Runners	-3.233*	1.544	.039
Body Fat Percentage	Weight Lifters	Long-Distance Runners	1.663*	0.466	.001
		Yoga Practitioners	-1.704*	0.466	.000
	Long Distance Runners	Weight Lifters	-1.663*	0.466	.001
		Yoga Practitioners	-3.367*	0.466	.000
	Yoga Practitioners	Weight Lifters	1.704*	0.466	.000
		Long-Distance Runners	3.367*	0.466	.000
Skeletal Muscle Mass	Weight Lifters	Long Distance Runners	3.967*	0.584	.000
		Yoga Practitioners	2.322*	0.584	.000
	Long Distance Runners	Weight Lifters	-3.967*	0.584	.000
		Yoga Practitioners	-1.645*	0.584	.006
	Yoga Practitioners	Weight Lifters	-2.322*	0.584	.000
		Long Distance Runners	1.645*	0.584	.006

* The mean difference is significant at the 0.05 level

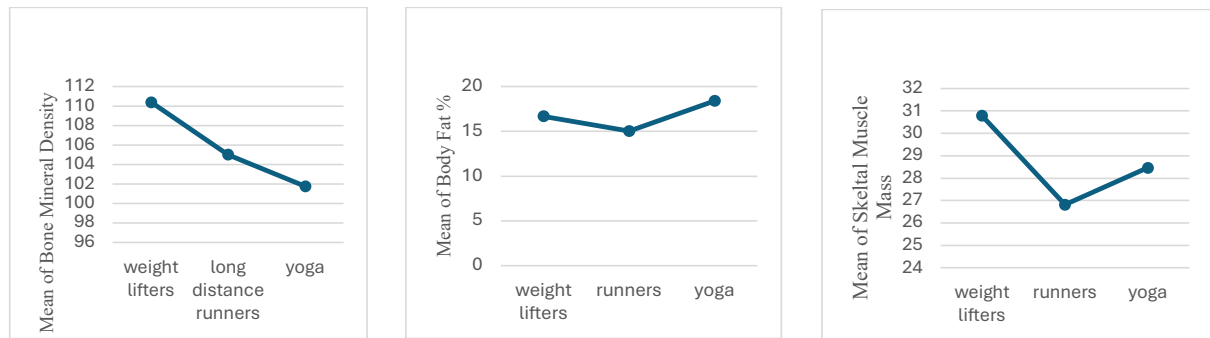


Fig. 1. Showings mean plots of variables between groups

A post-hoc LSD test (Table 4) revealed significant differences between the groups for all parameters. For bone mineral density, weight lifters had significantly higher values than long-distance runners ($p = .001$) and yoga practitioners ($p = .000$), and long-distance runners had higher values than yoga practitioners ($p = .039$). Regarding body fat percentage, long-distance runners had lower percentages than weight lifters ($p = .001$) and yoga practitioners ($p = .000$), with weight lifters also having lower body fat than yoga practitioners ($p = .000$). For skeletal muscle mass, weight lifters showed greater mass compared to long-distance runners ($p = .000$) and yoga practitioners ($p = .000$), with yoga practitioners having more muscle mass than long-distance runners ($p = .006$).

Discussion

The present study revealed significant differences in bone mineral density (BMD), body fat percentage, and skeletal muscle mass across three groups of athletes: weight lifters, long-distance runners, and yoga practitioners. Weightlifters exhibited the highest bone mineral density (BMD) among the groups, which is consistent with research showing that high-intensity mechanical loads, such as those encountered during weightlifting, stimulate bone adaptation and enhance BMD (Kohrt et al., 2010; Kohrt et al., 2004). The mechanical stress induced by the loading forces of weightlifting leads to significant bone strengthening (Souza et al., 2020; Hackett & Sabag, 2021). In contrast, long-distance runners had moderate BMD. Although running provides mechanical load, it is less intense than weightlifting, which may explain why runners have lower BMD compared to weightlifters (Tenforde et al., 2011). The continuous, moderate impact of endurance running contributes positively to bone health but falls short of achieving the higher BMD that weightlifting promotes (Borer, 2005; Kohrt et al., 2004). Meanwhile, yoga practitioners had the lowest BMD, likely due to the lower impact of yoga. Despite incorporating weight-bearing poses, yoga does not generate sufficient mechanical stress to significantly enhance BMD (Fernández-Rodríguez et al., 2021; Greendale et al., 2002).

Skeletal muscle mass is a crucial component of overall physical health and well-being, particularly during the formative years of youth. Maintaining optimal skeletal muscle mass can have far-reaching benefits, from improved physical performance to the prevention of age-related muscle loss (sarcopenia) later in life (Aversa et al., 2019; Tieland et al., 2018). Study found that weightlifters had the

highest skeletal muscle mass, which is a direct result of the hypertrophic effects of resistance training (Hackett & Sabag, 2021; Benito et al., 2020). Mechanical loads and muscle contractions during weightlifting promote muscle size and strength through increased protein synthesis and muscle fiber recruitment (Morton et al., 2016; Schoenfeld, 2010). In contrast, long-distance runners exhibited the lowest skeletal muscle mass, as their training focuses on endurance and cardiovascular efficiency rather than hypertrophy. The high energy expenditure during endurance exercise can lead to muscle breakdown rather than growth, as muscle development is not prioritized in this type of training (Konopka & Harber, 2014; Fyfe et al., 2014). Enhance the eccentric strength of the hamstrings, significantly reducing the risk of muscle strains in athletes participating in high-intensity sports (Islam et al., 2024). Yoga practitioners displayed moderate skeletal muscle mass. While yoga involves isometric contractions that help maintain muscle mass, the intensity and frequency of muscle engagement are lower than those seen in weightlifting, resulting in more modest muscle development (Cramer et al., 2013; Ross & Thomas, 2010).

Long-distance runners showed the lowest body fat percentage among the groups, corresponding to the high caloric expenditure and fat oxidation associated with sustained aerobic activity (Mooses et al., 2013). The prolonged aerobic nature of endurance running leads to increased fat metabolism and energy expenditure, making it highly effective for fat reduction (Willis et al., 2012). Weightlifters, while having a higher body fat percentage than runners, maintained lower fat levels than yoga practitioners. Increased muscle mass from resistance training elevates basal metabolic rate and facilitates fat loss (Kraemer & Ratamess, 2004; Schoenfeld, 2010). Yoga practitioners had the highest body fat percentage, likely due to the lower intensity and caloric expenditure of yoga compared to weightlifting and running. According to Lauche et al. (2016), yoga does not promote the same level of metabolic activity necessary for substantial fat reduction due to its focus on flexibility, balance, and mental health (Cowen & Adams, 2005).

Conclusions

Weightlifting is the most effective method for increasing muscle mass and bone mineral density while maintaining lower body fat levels. Long-distance running, which emphasizes endurance, leads to decreased muscle mass,

moderate bone mineral density, and lower body fat. Yoga has minimal impact on muscle mass and bone mineral density but can help maintain muscle through isometric contractions during poses. These results suggest that combining exercise modalities provides a balanced approach to improving overall health, combining the fat loss and cardiovascular benefits of endurance training with the muscle and bone-building effects of resistance training.

Limitations

This study had a cross-sectional design, which limits the ability to establish causal relationships between training programs and the observed differences in skeletal muscle mass, body fat percentage, and bone mineral density. Additionally, the sample size of 90 participants, with 30 in each group, may be relatively small, potentially affecting the generalizability of the findings. Furthermore, the study did not account for confounding variables, such as diet and individual training intensity, which could have influenced the results. Future research should consider using longitudinal designs and controlling for these variables to provide a more comprehensive understanding of the effects of different athletic disciplines on body composition and bone health.

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Conflicts of Interest

The authors declare no conflicts of interest.

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Оцінка впливу спортивних дисциплін на композицію тіла та здоров'я кісткової тканини: Акцент на заняттях йогою, важкою атлетикою та бігом на довгі дистанції

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

Реферат. Стаття: 8 с., 3 табл., 1 рис., 52 джерела.

Історія питання. Розуміння того, як різні види спорту впливають на стан кісткової тканини та композицію тіла, є ключовим чинником для покращення спортивної результативності та загального самопочуття. Важка атлетика, йогою та біг на довгі дистанції мають унікальний вплив на організм. Це дослідження містить аналіз того, як конкретні спортивні дисципліни формують здоров'я кісткової тканини та композицію тіла, а також надає цінні рекомендації щодо поліпшення рівня фізичної підготовленості та стану здоров'я.

Мета дослідження. Дослідження мало на меті оцінити вплив занять важкою атлетикою, йогою та бігом на довгі дистанції на композицію тіла та мінеральну щільність кісткової тканини, а також визначити, наскільки суттєво ці види фізичної активності впливають на обидва фактори.

Матеріали та методи. За методом рандомізації було відібрано дев'яносто (N = 90) міжуніверситетських спортсменів. Вибірка складалася з бігунів на довгі дистанції (n = 30), спортсменів-важкоатлетів (n = 30) та практиків йогою (n = 30). Вимірювання мінеральної щільності кісткової тканини проводилось за допомогою аналізатора мінеральної щільності кісткової тканини "Achilles EXPII" (Частина 1), що передбачає ультразвукове дослідження п'яткової кістки, а композиція тіла оцінювалась із використанням тест-системи "GS6.5B Body Building Weight Test System" (Версія 1.0) з метою визначення компонентного складу маси тіла спортсменів.

Результати. Спостерігалися значні відмінності між групами за показниками мінеральної щільності кісткової тканини $F_{(2,87)} = 15,95$, $p = 0,000$, відсоткового вмісту жиру в організмі $F_{(2,87)} = 26,15$, $p = 0,000$ та маси скелетних м'язів $F_{(2,87)} = 23,30$, $p = 0,000$. Post-hoc тест найменшої значущої різниці показав, що важкоатлети мали найвищий рівень мінеральної щіль-

ності кісткової тканини та маси скелетних м'язів, тоді як бігуни на довгі дистанції продемонстрували найнижчий показник відсоткового вмісту жиру в організмі серед досліджуваних груп.

Висновки. За результатами дослідження встановлено суттєві відмінності у показниках маси скелетних м'язів, відсоткового вмісту жиру в організмі та мінеральної щільності кісткової тканини серед важкоатлетів, практиків йоги та бігунів на довгі дистанції. Отримані дані вказують на чітко виражені фізіологічні адаптації, пов'язані із кожним видом спорту, підкреслюючи необхідність розробки індивідуальних тренувальних та оздоровчих стратегій щодо оптимізації результативності та показників стану здоров'я в різних спортивних дисциплінах.

Ключові слова: композиція тіла, щільність кісткової тканини, м'язова маса, легкоатлет з бігу на витривалість, практик йоги, важка атлетика.

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Kencur Supplementation Modulates Interleukin-6 (IL-6) and C-Reactive Protein (CRP) in Response to Muscle Damage Following Eccentric Exercise

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Abstract

Background. Intense or unaccustomed exercise can cause muscle damage and tissue injury, leading to temporary muscle dysfunction and the release of pro-inflammatory cytokines and free radicals. These factors may result in muscle protein breakdown, impaired nutrient absorption, and hindered recovery.

Objectives. This study aimed to evaluate the effects of Kencur supplementation on plasma IL-6 and CRP levels following eccentric exercise.

Materials and methods. A randomized controlled trial (RCT) with a double-blind, placebo-controlled design was conducted with 40 male recreational students from the State University of Surabaya — Universitas Negeri Surabaya (age: 19.65 ± 1.09 years, BMI: 21.10 ± 1.16 kg, body fat percentage: $22.14\% \pm 2.14\%$). Participants were randomly assigned to either the Kencur group (200 mg/day) or the placebo group (corn starch 100 mg/day) for a period of 14 days. On the experimental day, participants performed 100 countermovement jumps (CMJ). Blood samples were collected immediately after, 24 hours, and 48 hours post-exercise to measure IL-6 and CRP levels. Repeated Measures ANOVA with Bonferroni Post-hoc tests were used to analyze the data.

Results. The Kencur group showed a significant reduction in plasma IL-6 and CRP levels post-exercise at all time points ($p < 0.05$), while the placebo group exhibited no substantial changes ($p > 0.05$).

Conclusions. The findings indicate that Kencur supplementation significantly reduces the inflammatory response by lowering IL-6 and CRP levels following eccentric exercise.

Keywords: eccentric exercise, ROS, inflammation, immune response.

Introduction

Intense or unaccustomed exercise can result in muscle damage and tissue injury, often leading to a temporary loss of muscle function and the release of pro-inflammatory cytokines and free radicals (Aoi et al., 2004; Suzuki, 2018; Wilke & Behringer, 2021). Among various exercise modalities, eccentric exercise—where muscles lengthen

while contracting, such as during the lowering phase of a weightlifting movement—induces greater muscle cell damage and post-exercise discomfort compared to concentric exercise, which involves muscle shortening (Hotfiel et al., 2018; Lin et al., 2021). Eccentric exercise places significant mechanical strain on the muscle, particularly affecting the sarcolemma, the protective membrane surrounding muscle fibers (Bazzucchi et al., 2019; Peake, 2019). This strain can result in structural disruptions, such as Z-line streaming in the sarcomere, and leakage of intracellular proteins into the bloodstream, impairing muscle function and reducing force production capacity (Lee et al., 2021; Northeast & Clifford, 2021; Sonkodi, 2022).

Following such muscle damage, individuals typically experience delayed-onset muscle soreness (DOMS), peaking between 24 to 72 hours post-exercise. DOMS is associated with localized inflammation and the mobilization of immune cells to the affected tissues (Farias-Junior et al., 2019; Sulistyarto et al., 2022). This process resembles the acute-phase response seen in trauma or infection, characterized by increased levels of oxidative stress and inflammatory markers (Stožer et al., 2020). Reactive oxygen species (ROS), generated during prolonged or intense exercise, contribute to cellular damage and amplify the inflammatory response, further promoting the release of pro-inflammatory cytokines such as Interleukin-1 β (IL-1 β), Interleukin-8 (IL-8), tumor necrosis factor-alpha (TNF- α) and interleukin-6 (IL-6) (Thirupathi et al., 2021; Tidball & Villalta, 2010).

Among these cytokines, IL-6 exhibits the most significant elevation following exercise, with circulating levels increasing up to 100-fold depending on exercise intensity and duration (Fleckenstein et al., 2021). IL-6 is released into the circulation by contracting muscles (i.e., muscle-derived IL-6) during intense exercise (Beba et al., 2022; Nieman et al., 2003). IL-6 reaches its peak immediately after completion of exercise, followed by a rapid decline to baseline levels (Hennigar et al., 2017; Waskiw-Ford et al., 2020). If tissue damage occurs during intense exercise (e.g., vigorous eccentric exercise), immune cells infiltrate the muscle and release IL-6 to signal the acute phase response and tissue repair (Batatinha et al., 2019; Brendler et al., 2021).

While IL-6 plays a critical role in initiating tissue repair and adaptation, excessive levels can have deleterious effects, such as muscle protein breakdown, impaired nutrient uptake, and disrupted recovery (Kistner et al., 2022). Similarly, CRP, an acute-phase protein synthesized in response to IL-6, serves as an indicator of systemic inflammation and muscle damage severity. Prolonged elevations of these markers are linked to suboptimal recovery and impaired training outcomes (Peake et al., 2017).

Given the physiological impact of eccentric exercise, nutritional interventions aimed at mitigating exercise-induced inflammation have gained traction in recent years. Common strategies include supplementation with antioxidants (e.g., vitamins C and E) (Torre et al., 2021), anti-inflammatory compounds (Kruk et al., 2021), and proteins or amino acids (Gao et al., 2022; Northeast & Clifford, 2021). However, reliance on pharmacological anti-inflammatory agents, such as Nonsteroidal Anti-inflammatory Drugs (NSAIDs) like ibuprofen, is commonly used to reduce inflammation but may have side effects. This is associated with risks such as gastrointestinal distress and impaired tissue healing (Pham & Spaniol, 2024). This has shifted focus toward natural alternatives, including herbal supplements, as safer and potentially effective options.

Kencur (*Kaempferia galanga* Linn), a traditional herb from the Zingiberaceae family, has shown promise due to its potent anti-inflammatory properties (Irawan et al., 2022; Yao et al., 2018). Kencur contains bioactive compounds such as flavonoids, polyphenols, and ethyl p-methoxycinnamate, which have been associated with reductions in inflammatory markers (Kiptiyah et al., 2021). Preliminary studies suggest that Kencur supplementation may attenuate IL-6 and CRP responses following intense exercise, providing a natural approach to modulating the inflammatory cascade (Zhang et

al., 2022). However, current research on Kencur in exercise recovery contexts remains limited, often involving small sample sizes and early-phase studies. Therefore, this study aims to evaluate the effects of Kencur supplementation on plasma IL-6 and CRP levels following eccentric exercise. By assessing these inflammatory markers, we seek to determine whether Kencur supplementation can modulate the post-exercise inflammatory response and support muscle recovery. This study addresses a critical gap in the literature and contributes to the growing exploration of traditional herbal remedies in modern sports science.

Materials and Methods

Study Participants

A total of 40 male recreational students from Universitas Negeri Surabaya were participated in this study. The participants were carefully selected according to specific criteria; all were healthy with a normal body mass index (BMI), excluding those who were already taking medications, using chemical substances, or consuming any supplements, and did not smoke and alcohol. Additionally, both groups were deemed to be at low risk of bias. Participants were then randomly divided into two groups: one group received kencur capsules (Kencur Group, $n = 20$) and the other group received a placebo capsules (Placebo Group, $n = 20$). The participants had the same body weight, and there were no significant differences in physical characteristics between the two groups. Prior to participating in the research, all individuals gave their explicit consent after being thoroughly briefed on the study's goals and methods.

Study Organization

Randomized controlled trial (RCT) with a double-blind, placebo-controlled design. This approach ensures robust comparisons and minimizes biases. The design was developed to investigate the effectiveness of 200 mg of Kencur capsule supplementation for 14 days (2 weeks) to modulates IL-6 and CRP as inflammation and muscle damage markers. The study was conducted over a period of one month, with an initial assessment on the first day to evaluate the participants' baseline condition. Participants were prohibited from engaging in vigorous physical activity, including exercise, for the 30 days of the study. The only exception was an experimental exercise protocol, which was specifically designed for this study.

Supplementation

Both the Kencur group and the Placebo group participants collected their initial data, which included body weight, height, body fat percentage, physical activity level, and VO₂max measurements, to ensure that the groups were homogeneous at the outset of the study. The study involved two types of supplements: one containing 200mg of Kencur by Tazzaka™, a commercially available product, and another placebo consisting of a similar capsule with 100mg of corn starch. The Kencur supplement used in this study was manufactured by Tazzaka™ and is certified by the Indonesian Food and Drug Authority (Badan Pengawas Obat dan Makanan, BPOM). The subjects took either the Kencur supplement or the placebo capsule daily with breakfast for a

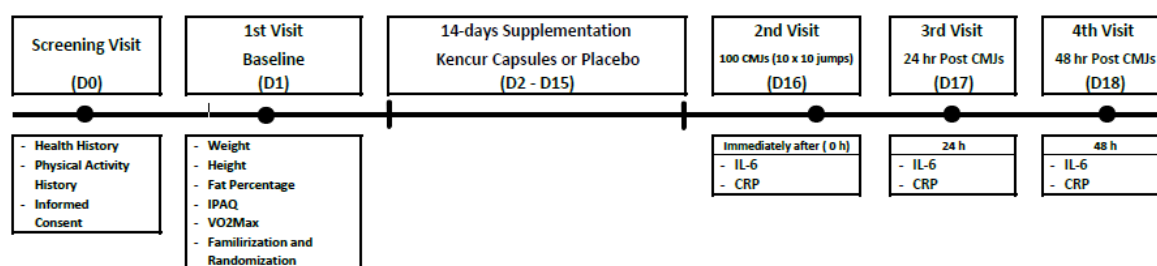


Fig. 1. Timeline of the study

period of 14 days. During this time, they were not allowed to engage in strenuous physical activity or participate in recovery programs such as massage or cryotherapy. Before starting any exercise, participants were required to be free from pain and injury, as confirmed by their completion of a physical activity readiness questionnaire.

Exercise Protocol

After 14 days of supplementation, on the 15th day, participants were asked to perform a specific exercise protocol designed to cause muscle damage. The protocol involved a series of countermovement jumps (CMJ) with proper technique and maximum effort encouraged. Participants performed a total of 100 countermovement jumps in 10 sets of 10 jumps every four seconds, with a 60-second rest between sets. The observer monitored the knee angle between jumps, ensuring it was maintained at 90°. This exercise has been proven to induce significant muscle damage in previous studies and was used to assess the effects of the supplements on muscle damage. A summary of the study design is presented in Figure 1.

Outcome Measures

The primary outcomes of the study were to measure IL-6 and CRP plasma concentration as an inflammatory marker due to eccentric exercise. The assessment of IL-6 and CRP plasma concentrations was performed at three specific time points: immediately after (0 h), 24 hours (24 h), and 48 hours (48 h) the countermovement jumps (CMJ) protocol was completed. The selection of specific time points (0 h, 24 h, and 48 h) is based on their established relevance in tracking post-exercise inflammatory responses, as demonstrated in previous studies (Kimble et al., 2023; Northeast & Clifford, 2021).

To assess IL-6 and CRP plasma concentration levels, blood samples were collected from the cubital vein, with up to 100 cc of blood taken and anticoagulated with EDTA, and placed into an SST (Serum Separator Tube). The tube with the frozen blood was then centrifuged at 3000 rpm for 15 minutes to separate the plasma from the blood. The plasma formed in the tube was transferred into several polypropylene tubes, sealed, and labeled with identity according to the research serial number. The tubes were then frozen at a temperature of $\leq -20^{\circ}\text{C}$ until analyzed.

Measurement of plasma IL-6 levels was performed using the Enzyme-Linked Immunosorbent Assay (ELISA) method, while the plasma concentration of CRP was measured using the DBC hs-CRP ELISA kit (Diagnostics Biochem Canada Inc., Canada). The analysis was conducted at the Sports Science

Laboratory of Universitas Negeri Surabaya and the Research Laboratory Installation of Airlangga University Hospital, which adhere to standard research protocols. Both laboratories are equipped for biochemical analysis, ensuring the reliability of the obtained IL-6 and CRP plasma concentration data.

Statistical Analysis

The data were processed both manually and digitally to convert it into usable information. Data are presented as mean $\pm$ standard deviation. Prior to the analysis, normality was assessed for the data distribution in each group and time point using the Shapiro-Wilk test. To evaluate the effects of Kencur supplementation on the dependent variables, IL-6 and CRP levels were analyzed using Repeated Measures ANOVA with two factors: time (0 h, 24 h, and 48 h) as a within-subject factor and treatment group (kencur supplementation vs. placebo) as a between-subject factor. If the ANOVA results show significant differences, post-hoc testing using Tukey's HSD will be conducted to identify specific differences between time points (0 h, 24 h, and 48 h) within each treatment group. All analyses will be performed using SPSS 23 statistical software, with a significance level set at $p < 0.05$.

Results

A total of 40 recreational male students from Universitas Negeri Surabaya participated in this study. They were randomly assigned to either the Kencur Group ($n = 20$) or the Placebo Group ($n = 20$). The average age of the Kencur Group was 18.70 years (± 0.47), while the average age of the PLA was 18.67 years (± 0.49).

The International Physical Activity Questionnaire (IPAQ) was used to assess participants' activity levels before the study commenced, categorizing them as low, moderate, or high activity based on metabolic equivalent task (MET) values. Body composition was measured using bioelectrical impedance analysis, while aerobic fitness was estimated via the $\text{VO}_{2\text{max}}$ test using the Beep Test (Multistage Shuttle Run Test).

Additional characteristics from this study are presented in Table 1. (Data are presented as mean $\pm$ standard deviation (SD), $n = 20$).

Kencur supplementation and changes on IL-6

IL-6 is a cytokine that serves as a marker of inflammation in response to the mechanical disruption of fibers. IL-6 plasma levels were measured at three different times: immediately after (0 h), 24 hours (24 h), and 48 hours (48 h) post-eccentric exercise. The plasma levels of IL-6 increased

Table 1. Respondent Characteristic

Indicators	Kencur Group	Placebo Group	Categories
Age (years)	19.65 ($\pm$ 1.09)	19.70 ($\pm$ 1.17)	
Height (cm)	166.30 ($\pm$ 5.32)	167.75 ($\pm$ 3.13)	
Weight (kg)	58.65 ($\pm$ 4.83)	59.15 ($\pm$ 3.53)	
BMI	21.19 ($\pm$ 1.24)	22.50 ($\pm$.66)	Normal
Fat Percentage (%)	21.94 ($\pm$ 2.20)	22.33 ($\pm$ 2.11)	Average
IPAQ (MET)	1318.26 ($\pm$ 252.48)	1266.63 ($\pm$ 214.28)	Moderate
VO ₂ max (mL·kg ⁻¹ ·min ⁻¹)	34.84 ($\pm$ 6.18)	36.89 ($\pm$ 5.87)	Poor

in response to exercise in both groups. Peak IL-6 levels were observed immediately (0 h) post-exercise for both Kencur and placebo groups, followed by a decrease at 24 h and a subsequent increase at 48 h after eccentric exercise.

When compared to the placebo group, the Kencur group showed significantly lower IL-6 plasma values at all time points post eccentric exercise (Table 2). (Data are presented as mean $\pm$ standard deviation (SD), n = 20).

Table 2. Changes in IL-6 plasma were measured at three different times.

IL-6	0 h (pg/ml)	24 h (pg/ml)	48 h (pg/ml)	P
Kencur	45.65 $\pm$ 17.22	23.26 $\pm$ 18.23	29.28 $\pm$ 18.54	0.001
Placebo	75.26 $\pm$ 26.25	57.90 $\pm$ 22.21	65.66 $\pm$ 20.17	0.710

Repeated Measures ANOVA with two factors

Table 2 above shows the changes in IL-6 after a 2-week supplementation period for both the Kencur and Placebo groups. The p-value (time) indicates the significance of differences in IL-6 levels across the three time points (0 h, 24 h, and 48 h) within each group. In contrast, the Placebo group did not exhibit significant changes in IL-6 levels over time (p = 0.710), suggesting no measurable effect from the placebo intervention. This implies that Kencur supplementation resulted in reduced IL-6 plasma levels, while the placebo group did not see any reduction in IL-6 plasma levels.

Kencur supplementation and changes on inflammatory marker (CRP)

CRP is frequently used as an indicator of inflammation resulting from intense exercise. In a comparative study of plasma levels of inflammatory markers before and after kencur supplementation (after a 2-week period), we noted a significant change in CRP levels across the three time points (0 h, 24 h, and 48 h) within each group in the kencur group, while no such change was observed in the placebo group. The test results are shown in Table 3 below. (Data are presented as mean $\pm$ standard deviation (SD), n = 20).

Table 3. The changes in CRP plasma levels were measured at three different time points

hs-CRP	0 h (mg/l)	24 h (mg/l)	48 h (mg/l)	P
Kencur	2.42 $\pm$ 0.22	1.61 $\pm$ 0.16	1.74 $\pm$ 0.28	0.003
Placebo	2.65 $\pm$ 0.15	2.08 $\pm$ 0.17	2.36 $\pm$ 0.20	0.612

Repeated Measures ANOVA with two factors

Table 3 above shows the changes in plasma CRP after a 2-week supplementation period for both the Kencur and placebo groups. The results indicate a significant reduction in CRP levels over time (p < 0.001), suggesting a notable anti-inflammatory effect of Kencur supplementation. In contrast, CRP levels in the placebo group showed changes that were not statistically significant (p = 0.612), indicating no measurable effect from the placebo treatment. Therefore, it can be concluded that Kencur supplementation leads to a more pronounced decrease in CRP plasma levels compared to the placebo.

Discussion

This study investigated the effects of Kencur (*Kaempferia galanga* Linn) supplementation on plasma IL-6 and CRP concentrations following eccentric exercise, a well-established model for inducing muscle damage and inflammation. The aim was to explore its potential as an anti-inflammatory agent in eccentric exercise, enhancing recovery, and improving exercise performance by leveraging its anti-inflammatory pathway. This information can serve as a reference and consideration for athletes and active individuals regarding the risk of inflammatory response and muscle damage caused by eccentric exercise.

The primary finding of this study showed that taking kencur supplements for a 2-week period can attenuate the inflammatory response and prevent muscle damage, as indicated by significant changes in both IL-6 and CRP plasma levels, which are markers of inflammation and muscle damage due to eccentric exercise. The current findings support kencur supplementation to attenuate inflammation and muscle damage in the hours immediately following eccentric exercise. Thus, kencur supplementation may be an important consideration in developing and implementing strategies to aid in muscle recovery during the acute (0-48 h) time period following a bout of eccentric exercise-induced inflammation.

The benefits of taking kencur supplements before and after exercise-induced inflammation are uncertain due to variations in dosage, timing, and types of exercises studied. Inflammation and muscle damage levels also differed among the studies.

It has been shown in many studies that eccentric exercise, especially if done excessively, can result in inflammation and muscle damage (Bontemps et al., 2020). High intensity exercise can cause a temporary decrease in muscle strength, increased passive tension, increased pain and muscle inflammation, and elevated levels of intramuscular proteins in the bloodstream (Arazi et al., 2021). It is a common

symptom that occurs when engaging in high-intensity exercise. It is a temporary and natural part of the muscle's repair and adaptation process (Batatinha et al., 2019).

Eccentric exercise, characterized by muscle lengthening while contracting—such as during the lowering phase of a weightlifting movement—places unique and intense mechanical stress on muscle fibers. This type of exercise is not only more challenging than concentric exercise, where the muscle shortens, but it also elicits a distinct physiological response due to the higher strain it imposes on muscle structures (Heiss et al., 2019; Stožer et al., 2020). The sarcolemma, a critical membrane surrounding muscle fibers, is particularly vulnerable during eccentric contractions. Microscopic examination reveals structural disruptions, such as "Z-line streaming" within the sarcomere, the fundamental unit of muscle contraction (Uçar et al., 2024). These changes compromise the integrity of the muscle and can lead to the leakage of essential intracellular proteins, such as creatine kinase, into the bloodstream—a hallmark of muscle damage (Stožer et al., 2020).

The resulting impairment in muscle function significantly decreases the muscle's capacity to produce force, contributing to post-exercise soreness and a prolonged recovery period (Barker et al., 2023). Despite these challenges, eccentric exercise is highly valued for its ability to stimulate muscle remodeling and adaptation, making it a double-edged sword in physical training and rehabilitation. IL-6 is the most significantly elevated cytokine after intense exercise, often exceeding other cytokines by up to 100-fold (Nanavati et al., 2022). High levels of IL-6 can lead to muscle protein breakdown, hinder recovery, and disrupt training adaptations, impacting performance and long-term health.

Several studies have suggested a strong link between inflammation and muscle recovery. Inflammatory responses, particularly through IL-6 and CRP pathways, play a crucial role in post-exercise adaptation and tissue repair (Irawan et al., 2022; Jakubczyk et al., 2020). This response involves the release of pro-inflammatory cytokines such as tumor necrosis factor- α (TNF- α), interleukin-1 beta (IL-1 β), and interleukin-6 (IL-6), as well as other inflammatory mediators like prostaglandins and leukotrienes (Lin et al., 2021). These cytokines not only amplify the inflammatory process but also contribute to the recruitment and activation of immune cells, perpetuating a cycle of oxidative damage and inflammation (Suzuki, 2018; Tanabe et al., 2021).

Studies have demonstrated that muscle damage is frequently associated with oxidative stress (OS), which is marked by an increase in reactive oxygen species (ROS). The level of the biomarker produced is dependent on the extent of muscle damage or fatigue. One study observed that cytokines response and muscle damage during eccentric exercise have been linked to a shift toward greater glycolytic energy production. As a result, inflammatory processes are consistently connected with OS, and both are directly involved in muscle damage, meaning they should be examined and managed together (Amalraj et al., 2020).

Preventing excessive increases in IL-6 following eccentric exercise is important because sustained high levels of IL-6 are associated with detrimental effects such as muscle protein breakdown, prolonged inflammation, and impaired recovery (Jomova et al., 2023; Waskiw-Ford et al., 2020). IL-6 is a pleiotropic cytokine that plays a dual role: while it acts as

a myokine facilitating glucose uptake and tissue repair during moderate elevation, excessive levels can shift toward pro-inflammatory actions, promoting catabolic effects (Fuller et al., 2020; Kistner et al., 2022). Elevated IL-6 also stimulates the production of acute-phase proteins like CRP, exacerbating systemic inflammation and contributing to oxidative stress, which can delay muscle regeneration and adaptation (Boukhris et al., 2020; Del Giudice & Gangestad, 2018).

Studies have shown that unchecked inflammation marked by elevated IL-6 levels can impair mitochondrial function, amplify muscle soreness, and reduce force production, potentially leading to overtraining syndrome or compromised athletic performance (Fischer et al., 2004). Therefore, nutritional or therapeutic strategies targeting IL-6 modulation, such as antioxidant or anti-inflammatory supplementation, can help maintain an optimal inflammatory balance post-exercise, supporting recovery and training benefits (Nara & Watanabe, 2021).

In this study, IL-6 and CRP plasma concentrations in blood were measured as an inflammatory marker. As shown in the results above, there is changes in both IL-6 and CRP plasma levels 0 hours, 24 hours and 48 hours post single bout eccentric exercise. The results of statistical analysis showed that there is a difference in IL-6 and CRP plasma levels after 14 days of Kencur supplementation. Recent studies have also shown a slight increase in IL-6 and CRP levels as an inflammatory marker after CMJs as an EIMD (Cerqueira et al., 2020; Costello et al., 2018; Kawamura & Muraoka, 2018). The presence of this inflammatory marker (IL-6 and CRP) is suggested to be the result of muscle cell damage as a consequence of intense eccentric exercise (Boukhris et al., 2020; Mal'tseva et al., 2022). The present study showed that daily Kencur capsules intake demonstrated to be efficient in attenuating IL-6 and CRP plasma levels as a consequence of intense eccentric exercise.

The excessive inflammatory response that follows can ultimately lead to additional tissue damage (Taherkhani et al., 2020). Previous evidence has suggested that an acute bout of exercise increases NF- κ B activity. NF- κ B is a critical regulator of various physiological and pathological processes, including inflammation and oxidative stress (Suzuki et al., 2020).

In conclusion, this study provides evidence supporting the potential of kencur supplementation to modulate exercise-induced inflammation, as indicated by its effects on plasma IL-6 and CRP levels following eccentric exercise. The anti-inflammatory pathway of kencur, attributed to its bioactive compounds such as ethyl p-methoxycinnamate and flavonoids, appear to play a crucial role in attenuating the acute inflammatory response associated with muscle damage. These findings suggest that kencur may serve as a natural and effective alternative for managing post-exercise inflammation, promoting recovery, and maintaining training adaptations. However, further research involving larger sample sizes, diverse populations, and varying exercise protocols is necessary to confirm these effects and explore the broader applications of kencur in sports and clinical settings.

Conclusions

This study demonstrates the potential of kencur supplementation to modulate inflammatory responses following eccentric exercise. Specifically, kencur

supplementation was associated with reductions in plasma IL-6 and CRP concentrations following eccentric exercise, suggesting a potential role in modulating the inflammatory response. These findings suggest that kencur, with its anti-inflammatory properties, may serve as a natural and effective strategy to mitigate exercise-induced muscle damage (EIMD).

Future research should explore the dose-response relationship and long-term effects of kencur supplementation across diverse populations and exercise modalities. Additionally, comparative studies with other anti-inflammatory interventions could further establish kencur's role as a viable alternative in sports nutrition and recovery.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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Приймання добавок із вмістом кенкура модулює показники інтерлейкіну-6 (IL-6) та С-реактивного білка (CRP) як реакція на пошкодження м'язів після виконання ексцентричних вправ

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Реферат. Стаття: 9 с., 3 табл., 1 рис., 55 джерел.

Історія питання. Інтенсивні або некастомізовані фізичні вправи можуть спричинити пошкодження м'язів і травмування тканин, що призводить до тимчасової м'язової дисфункції і вивільнення прозапальних цитокінів та вільних радикалів. Вказані фактори можуть викликати розпад м'язових білків, порушення засвоєння поживних речовин та уповільнення процесу відновлення.

Мета дослідження. Метою цього дослідження було оцінити вплив приймання добавок із вмістом кенкура на рівні ІЛ-6 та С-реактивного білка в плазмі крові після виконання ексцентричних вправ.

Матеріали та методи. Проведено рандомізоване контрольоване дослідження (РКД) із застосуванням подвійного сліпого, плацебо-контрольованого дизайну за участю 40 студентів чоловічої статі, які навчалися на факультеті рекреації Державного університету Сурабаї — Universitas Negeri Surabaya (вік: $19,65 \pm 1,09$ років, ІМТ: $21,10 \pm 1,16$ кг, відсотковий вміст жиру в організмі: $22,14\% \pm 2,14\%$). Учасників було рандомізовано до групи, яка приймала добавки із вмістом кен-

кура (200 мг/добу), або до групи плацебо (кукурудзяний крохмаль 100 мг/добу) на період спостереження 14 днів. У день проведення експерименту учасники виконали 100 вертикальних стрибків із контррухом (КРС). Забір зразків крові проводився одразу після тренування, через 24 години та 48 годин після завершення вправ з метою визначення рівнів ІЛ-6 та С-реактивного білка. Для аналізу даних було застосовано метод дисперсійного аналізу повторних вимірювань (ANOVA) із використанням post-hoc-тестів Бонферроні.

Результати. У групі, яка приймала добавки із вмістом кенкура, спостерігалось достовірне зниження рівнів ІЛ-6 та СРБ у плазмі крові після тренування в усіх часових проміжках ($p < 0,05$), тоді як у групі плацебо суттєвих змін не встановлено ($p > 0,05$).

Висновки. Отримані дані свідчать про те, що вживання добавок із вмістом кенкура сприяє значному зменшенню запальної реакції за рахунок зниження рівнів ІЛ-6 та СРБ після виконання ексцентричних вправ.

Ключові слова: ексцентричні вправи, АФК, запалення, імунна відповідь.

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Combining High-Intensity Interval Training and Game-Based Approach to Enhance Aerobic Endurance in Amateur Futsal Athletes

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Abstract

Background. Futsal players require a holistic training model that combines high-intensity interval training with a game-based approach, addressing their need to cover a total distance of 4000 meters at maximum aerobic speed.

Objectives. This study aimed to analyze the effect of combining high-intensity interval training with a game approach on the aerobic ability of amateur futsal athletes.

Materials and methods. This study used an experimental method. A total of 32 male futsal athletes from amateur clubs participated in this study, with an age of 17.00 ± 1.10 years, a height of 167.19 ± 3.80 cm, a body mass of 58.81 ± 3.80 kg, and a BMI of 21.05 ± 1.26 . Data analysis used the Wilcoxon signed-rank test and the Mann-Whitney U test, with a significance level of 0.05. The total distance covered and the VO_{2max} level of the sample were measured using a 12-minute Cooper test instrument.

Results. The statistical analysis using the Wilcoxon and Mann-Whitney tests revealed that the Experimental Group (EG) showed significant enhancements in both Total Distance (TD) and VO_{2max} ($p < 0.0001$ for both), while the Control Group (CG) did not ($p = 0.0747$ for TD, $p = 0.0701$ for VO_{2max}). The Mann-Whitney test confirmed that the EG's improvements were significantly more marked than the CG's ($p < 0.0001$ for both variables). The percentage improvements between the pre-test and post-test show that in the EG, TD increased by 8.12%, and VO_{2max} increased by 10.44%. In contrast, the CG demonstrated only a 1.11% increase in TD and a 1.44% increase in VO_{2max} .

Conclusions. These findings concluded that combining a high-intensity interval training model with a game approach had a positive effect on the aerobic endurance of amateur futsal athletes.

Keywords: combination training, high-intensity interval training, game approach, aerobic, futsal amateur.

Introduction

In recent decades, the characteristics of the futsal game have evolved significantly, characterized by high game intensity and players who are more flexible in changing or rotating positions (Iván-Baragaño et al., 2022; Spyrou et al., 2020). Research studies investigating this sport modality

have also increased significantly over the last two decades (Barbero-Alvarez et al., 2008; Castagna et al., 2009; De Oliveira Bueno et al., 2014; Ohmuro et al., 2020), which contribute to a better understanding of the physical needs of players, the technical and tactical skills of players during the match, as well as the preparation of futsal training materials. According to the research study above, the average total distance traveled by futsal players in one match is around 4000-4500 meters, of which 8-13% is done in high-speed running ($HSR > 15.5$ km/h) and 5-9% is done in sprinting (> 18.3 km / h). Statistical data analysis can be practically beneficial in designing training programs, as match analysis is highly useful for developing specific training programs

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that resemble the physiological conditions of the game (Di Salvo et al., 2007).

Aerobic endurance is an essential modality to support the characteristics of playing futsal with high intensity because, with aerobic endurance, players will be helped to avoid fatigue or decreased performance, especially at the end of the match session (Glänzel et al., 2020; Milanez et al., 2011). There are previous research studies on physical training in futsal, such as (Campos et al., 2021; Laursen, 2010; Saleh et al., 2021) related to the high-intensity interval training model. Although this training model positively impacts physical abilities, it primarily focuses on physical improvement, potentially neglecting the development of technical and tactical skills essential for compelling gameplay. To address the gap identified in the study, researchers have developed new methods to overcome the issue. These innovative approaches aim to fill the existing void and enhance the overall understanding of the subject matter. By implementing these methods, researchers hope to achieve more accurate and relevant outcomes, ultimately contributing to the advancement of knowledge in this field and aligning with previous research that explains that futsal has a specific development of game dynamics, such as offensive (4-in-line) and defensive (pressure throughout the zone) (Naser et al., 2017).

In a sports coaching survey by Thompson (2023), high-intensity interval training is the most popular method to improve physical abilities, especially aerobic endurance. Research has shown that high-intensity interval training positively impacts players' aerobic endurance (Helgerud et al., 2007). Given the very high physical demands during the game, combining high-intensity interval training with game training adjusted to an average total distance of 4000 meters is important (Ribeiro et al., 2020). Therefore, it is necessary to scientifically study the impact of combining these exercises to meet specific futsal training needs. The results of this study can help coaches and players design more effective training programs that combine physical, technical, and tactical components according to the needs of players in a match. This study can also provide valuable insights into how futsal games at the amateur level can improve.

Materials and Methods

Study Participants

Thirty-two male futsal athletes from amateur clubs participated in this study. They were 17.00 ± 1.10 years old, 167.19 ± 3.80 cm tall, 58.81 ± 3.80 kg in body mass, and 21.05 ± 1.26 in BMI. All samples involved in this study had 1 year of physical training experience. The researchers randomly divided the sample into an experimental group (EG) and a control group (CG)

Study Organization

The researchers administered a pretest to the experimental and control groups to determine their initial aerobic endurance ability. Furthermore, the experimental group was given high-intensity interval training treatment with a game approach for four weeks with a frequency of three times a week. The control group was not given any

special treatment but continued to undergo training with the same duration and frequency as the experimental group. After four weeks of training, in the last week, the experimental and control groups were given a post-test to determine the difference in aerobic endurance ability with high-intensity interval training with a game approach. This study used the 12-minute Cooper Test. The 12-minute Cooper Test variables analyzed were VO_{2max} .

Training Program

The training program involves two groups of players, each consisting of 8 people, with a High-Intensity Interval Training (HIIT) approach that combines games and fast dribbling. Group 1, consisting of 8 players, trains in a four vs four with game format in a 15×15 meter area. Meanwhile, Group 2 undergoes fast dribbling training with a distance of 40 meters, repeated 10 times so that the total distance covered reaches 400 meters. After completing their respective tasks, the two groups switch roles, with a rest time equal to the duration required to complete the 400-meter dribble. Each player will complete five games and five fast dribbling sets in one training session. Thus, each player will cover a total distance of around 2000 meters, and the entire group will cover a distance of 4000 meters.

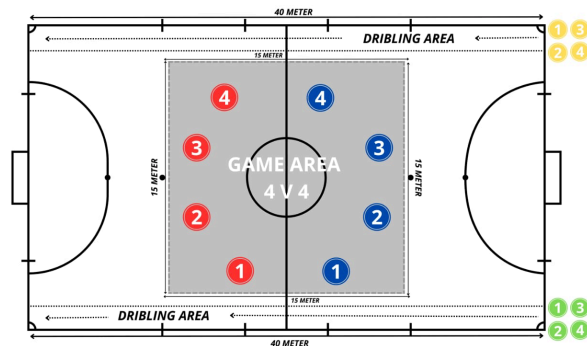


Fig. 1. HIIT Training and Game Combination Area

This program aims to improve the players' maximal aerobic capacity by emphasizing high intensity and high training volume. The combination of four vs four with games in a small area and fast dribbling in the HIIT pattern encourages players to work at high intensity repeatedly, which is very effective in increasing VO_{2max} (maximal oxygen consumption). This training aims to increase the players' cardiorespiratory system efficiency, improve their aerobic endurance, and optimize recovery between periods of intensive work, helping them achieve optimal levels of maximal aerobic capacity.

Statistical Analysis

This study presents the data as means and standard deviations and uses the Shapiro-Wilk test to assess normality. The researchers used the Wilcoxon test for non-normally distributed data and the Mann-Whitney test to compare differences between two non-normally distributed groups. The researchers calculated the percentage of improvement between pretest and post-test results during the training period using the formula: $(\text{mean difference} / \text{mean pretest}) \times 100\%$.

Results

Table 1. Characteristics Samples

Group	Age	Height (cm)	Weight (kg)	BMI
EG	17.00 ± 1.10	167.19 ± 3.80	58.81 ± 3.80	21.05 ± 1.26
CG	17.13 ± 1.09	167.31 ± 3.46	57.13 ± 3.61	20.42 ± 1.42

The data is presented as mean ± SD to indicate central tendency and variability

Table 1 above shows the demographic characteristics of the experimental group (EG) and the control group (CG). The average age of the experimental group is 17.00 ± 1.10 years, while the control group has an average age of 17.13 ± 1.09 years. For height, the experimental group has an average of 167.19 ± 3.80 cm, and the control group has an average of 167.31 ± 3.46 cm. In terms of weight, the experimental group has an average of 58.81 ± 3.80 kg, while the control group has an average of 57.13 ± 3.61 kg. Finally, the average BMI for the experimental group is 21.05 ± 1.26, while the control group has an average BMI of 20.42 ± 1.42.

Table 1. Characteristics Samples

Group	Age	Height (cm)	Weight (kg)	BMI
EG	17.00 ± 1.10	167.19 ± 3.80	58.81 ± 3.80	21.05 ± 1.26
CG	17.13 ± 1.09	167.31 ± 3.46	57.13 ± 3.61	20.42 ± 1.42

The data is presented as mean ± SD to indicate central tendency and variability

Table 2 above shows the results of the normality test using Shapiro-Wilk. In the Experimental Group (EG), Pre Total Distance and Pre VO₂max have a normal distribution ($p > 0.05$), while Post Total Distance and Post VO₂max are generally not distributed ($p < 0.05$). In the Control Group (CG), all pretest and post-test variables have a normal distribution ($p > 0.05$). For the change (delta), Delta Total Distance and Delta VO₂max in the EG have a normal distribution ($p > 0.05$), while in the CG, they are generally not distributed ($p < 0.05$). Based on these results, the researchers will apply the Wilcoxon test to assess differences in non-normally distributed data and the Mann-Whitney test to compare the experimental group (EG) and control group (CG) on variables that do not follow a normal distribution.

Figure 2 above presents the statistical analysis results using the Wilcoxon and Mann-Whitney tests to compare

the Experimental Group (EG) and Control Group (CG) on two variables: Total Distance (TD) in meters and VO₂max in ml·min⁻¹·kg⁻¹. For the TD variable, the Wilcoxon test results show that the EG experienced a significant increase between the pretest and post-test ($p < 0.0001$). In contrast, the CG did not show a significant difference ($p = 0.0747$). The Mann-Whitney test confirms that the increase in TD for the EG was significantly more significant than the CG ($p < 0.0001$). For the VO₂max variable, the Wilcoxon test indicates that the EG also experienced a significant increase between the pretest and post-test ($p < 0.0001$), while the CG showed no significant difference ($p = 0.0701$). The Mann-Whitney test again reveals that the increase in VO₂max for the EG was significantly more significant than that of the CG ($p < 0.0001$). These results indicate that the intervention in the EG was effective in improving performance related to distance covered and aerobic capacity (VO₂max)

Table 3 Percentage of improvement

Variable	Pretest	Post-test	Percentage Improvement (%)
EG TD (meter)	2316.25 ± 112.24	2501.88 ± 80.02	8.12
CG TD (meter)	2271.88 ± 85.18	2296.88 ± 90.97	1.11
EG VO ₂ max (ml·min ⁻¹ ·kg ⁻¹)	40.49 ± 2.51	44.46 ± 1.79	10.44
CG VO ₂ max (ml·min ⁻¹ ·kg ⁻¹)	39.50 ± 1.90	40.06 ± 2.03	1.44

The data is presented as mean ± SD to indicate central tendency and variability

Table 3 above shows the percentage improvements in Total Distance (TD) and VO₂max between pretest and post-test. In the Experimental Group (EG), TD increased by 8.12 %, and VO₂max increased by 10.44 %. Meanwhile, in the Control Group (CG), TD only increased by 1.11 %, and VO₂max increased by 1.44 %. The EG shows a higher percentage of improvement compared to the CG.

Discussion

The combination of high-intensity interval training with a game approach has a positive effect on increasing aerobic endurance. The improvement in aerobic endurance is closely related to the impact of the maximal aerobic speed control system during training sessions, which is essential for planning the training program and adjusting the training load, particularly during high-intensity intermittent training (Psarras & Bogdanis, 2024). The training program adapts high-intensity interval training with a game-based approach, using the average total distance of 4000 meters covered in a futsal match as a reference, and incorporates a maximal aerobic intensity more significant than 90 % Hrmax with a 1:1 interval ratio.

The selection of a high-intensity interval training program with a game approach is an essential aspect in efforts to achieve goals in futsal, in this context, to increase aerobic endurance. This unique training allows players to develop technical and tactical skills in situations similar to real matches. Conversely, the high-intensity interval training approach can improve physical quality (Stankovic et al., 2023).

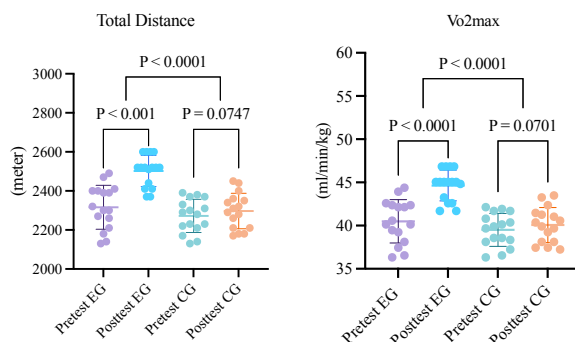


Fig. 2. Comparison of Total Distance and VO₂max between EG and CG

In the process, high-intensity interval training with a game approach will affect the increase in player confidence; this is because in each training session, the players not only focus on physical training but also technical and tactical skills so that it can indirectly improve the player's mentality (Méndez-Dominguez et al., 2022). Increasing training intensity gradually is also an effort to encourage physiological adaptation and improve player performance. In line with previous studies that the high-intensity interval method applied with the principle of progressiveness can coordinate muscle work simultaneously to produce optimal energy for motor performance and is the fastest way to obtain muscle development because it increases power production and protects joints from injury (Atakan et al., 2021; Liu et al., 2023).

Applying a training frequency of three times a week can affect aerobic endurance in amateur futsal athletes. Previous studies have reported that high-intensity interval training is practical when done in three sessions per week to reduce the adverse reactions due to glycogen depletion, accumulation of metabolites in muscles, and neuromuscular tension on athlete performance (Vigh-Larsen et al., 2021). In addition, this organized and continuous training will provide positive results in developing training goals (Barbieri et al., 2016).

The results of this study indicate that high-intensity interval training with a game approach can significantly increase aerobic endurance. In line with research As-Safa et al. (2024), rotational tactic training with a high-intensity interval training protocol can improve anaerobic performance in amateur futsal athletes. This training method can also be an alternative to improve several physiological parameters such as cardiometabolic, oxygen uptake kinetics, aerobic capacity, and resistance to muscle fatigue. The cardiometabolic increase in question is high-intensity interval training in increasing insulin sensitivity performance, which can help the body more efficiently regulate blood sugar levels (Weston et al., 2014). Increasing oxygen uptake kinetics is high-intensity interval training in increasing blood volume and hemoglobin, allowing muscle cells to use oxygen more quickly and efficiently during exercise (Buchheit & Laursen, 2013). The increase in aerobic capacity is due to high-intensity interval training in increasing cardiac output due to increased stroke volume and heart rate (Gibala & Jones, 2013). Meanwhile, the accumulation of lactic acid and hydrogen ions during high-intensity interval training triggers increased resistance to muscle fatigue, as these are the main factors causing muscle fatigue (Enoka & Duchateau, 2008).

This approach lets athletes experience game-like conditions during training, potentially increasing their match performance. However, it is essential to acknowledge the limitations of this study, including the small sample size and the short duration of the intervention, which may affect the generalizability of the results. Future research should consider more extensive, more diverse samples and explore the long-term effects of this training method on various physiological parameters in different age groups and competitive levels.

The findings of this study emphasize the effectiveness of combining high-intensity interval training with a game-based approach to enhance aerobic endurance in amateur futsal athletes. This approach can significantly benefit coaches in designing training programs that improve physical capabilities and integrate technical and tactical skills relevant to match scenarios.

Conclusions

Based on the research results achieved in high-intensity interval training with a game approach, the researchers concluded that this method can positively contribute to increasing aerobic endurance.

Conflict of Interest

The authors declare that there is no conflict of interest.

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Поєднання високоінтенсивного інтервального тренування та ігрового підходу сприяє підвищенню аеробної витривалості у футзалістів-аматорів

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

Реферат. Стаття: 6 с., 3 табл., 2 рис., 28 джерел.

Історія питання. Футзалісти потребують застосування холістичної моделі тренувань, яка передбачає поєднання високоінтенсивних інтервальних тренувань з ігровим підходом, що відповідає їхній необхідності долати загальну дистанцію 4000 метрів з максимальною аеробною швидкістю.

Мета дослідження. Мета дослідження полягала в аналізі впливу поєднання високоінтенсивного інтервального тренування з ігровим підходом на показники аеробної здатності футзалістів-аматорів.

Матеріали та методи. У цьому дослідженні застосовано експериментальний метод. Загалом у дослідженні взяли участь 32 футзалісти-чоловіки з аматорських клубів, вік яких становив $17,00 \pm 1,10$ року, зріст — $167,19 \pm 3,80$ см, маса тіла — $58,81 \pm 3,80$ кг, ІМТ — $21,05 \pm 1,26$. Для аналізу даних використовували критерій знакових рангів Уїлкоксона та U-критерій Манна-Уїтні з рівнем значущості 0,05. Загальна пройдена відстань і рівень максимального споживання кисню (VO_{2max}) вимірювалися за допомогою 12-хвилинного тесту Купера.

Результати. Згідно з результатами статистичного аналізу із застосуванням критеріїв Уїлкоксона та Манна-Уїтні встановлено, що експериментальна група (ЕГ) помітно покращила показники як загальної відстані (ЗВ), так і VO_{2max} ($p < 0,0001$ для обох змінних), тоді як контрольна група (КГ) не досягла істотного прогресу ($p = 0,0747$ для ЗВ, $p = 0,0701$ для VO_{2max}). За допомогою критерію Манна-Уїтні підтверджено, що покращення показників в ЕГ виявилися значно суттєвішими, ніж у КГ ($p < 0,0001$ для обох змінних). Відсоткове співвідношення поліпшень між даними перед початком і після завершення тестування свідчить про підвищення показників ЗВ в ЕГ на 8,12 %, а VO_{2max} — на 10,44 %. Натомість КГ продемонструвала лише зростання ЗВ на 1,11 % та VO_{2max} на 1,44 %.

Висновки. Отримані дані дозволяють зробити висновок, що поєднання моделі високоінтенсивного інтервального тренування з ігровим підходом позитивно впливає на аеробну витривалість спортсменів-аматорів з футзалу.

Ключові слова: комбіноване тренування, високоінтенсивне інтервальне тренування, ігровий підхід, аеробний, аматор з футзалу.

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Clarifying Differences in the Manifestation of Young Men's Motor Fitness Components in the Absence of Compulsory Physical Activity

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Abstract

Background. The current trend in the modernization of university physical education involves the development of a personal educational trajectory for each student.

Objectives. The study aimed to determine the peculiarities in the development of young male students' motor fitness components, taking into consideration their somatotypes and the absence of compulsory physical activity at the university.

Materials and methods. The study involved 39 young men aged 17.6 ± 0.5 years who had just started studying at the university, belonged to different somatotypes and had no restrictions in the use of different physical activity parameters. The somatotype was determined using the modified Stefko-Ostrovsky method. The 11 main components of motor fitness were examined, using motor tests recommended by researchers, appropriate testing methods and instruments. Each test met the requirements of reliability, informativeness and allowed to evaluate speed, frequency of movements, ability to balance, power, explosive strength of arms and legs, abdominal muscle strength, arm strength, flexibility, agility and aerobic endurance. The parameters of these components were determined in each available somatotype, and each parameter was compared with different somatotypes. Testing was conducted at the beginning (January) and at the end (May-June) of the academic semester, but during one academic year.

Results. At the beginning and at the end of the study, it was noted that there were differences in the development of motor fitness components among the various somatotypes when compared with each other (p at the level from 0.05 to 0.000). The volumes and conditions of physical activity realization used during the study contributed to the change of young men's results in some components. However, these alterations varied across different somatotypes.

Conclusions. The information about peculiarities of the development of motor fitness components among individuals with different somatotypes is important for increasing the efficiency of university physical education based on the personalization of content and differentiation of normative bases of this process.

Keywords: motor fitness, somatotypes, personalization, university physical education, physical activity, COVID-19.

Introduction

A complex of reasons of objective, but mostly subjective nature determines the low efficiency of physical education

in higher education institutions (hereinafter – university) despite its effectiveness and high potential in successfully solving a wide variety of tasks (Torres, Peneida, & Torres, 2022; Banah, & Iedynak, 2021; James et al., 2023). Due to this situation, the problem of modernizing physical education at the university continues to be relevant. Some important reasons for the need for this are largely due to the air raids characteristic of today as a result of the war with Russia, the

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consequences of quarantines during the Covid-19 epidemic (Piestrzyński et al., 2021; Limone et al., 2022; Byshevets et al., 2024). This has led to organizing the educational process at Ukrainian universities in the form of a mixed one, i.e., which involves traditional and distance learning (Dovgan, 2020; Andrieieva et al., 2023–2024).

Given the current situation, many domestic and foreign researchers emphasize the prospects and the need to continue scientific research in the personalization (individualization, differentiation) of university physical education. This will help to intensify the activities of teachers and students in the implementation of independent classes in practice by the latter in extracurricular time, as well as improve the quality of teachers' advisory services and their activities to strengthen the motivation of students to study in sports sections at the university, and other activities in extracurricular time (Coulter et al., 2016; Frąckiewicz, 2023). Some researchers (Banakh et al., 2023) emphasize the prospects of a methodological approach to personalization (individualization) of university physical education, based on a specific «educational route» for each student. However, this approach assumes the presence of a predictive and effective marker (except for gender), i.e., based on which homogeneous samples will be formed with the subsequent determination of the content of their physical activity program with optimal load parameters for each student (Wilmor et al., 2022).

It has been found that at the present stage, one of the most promising in terms of practical use is a marker-trait of a person as a somatotype (Cinarli, & Kafkas, 2019; Campa, & Greco, 2022). In this regard, it is important to know about the peculiarities of manifestation and changes in various characteristics of representatives of existing somatotypes over a certain age period. The main reason for this is the importance of such data for the formation of effective physical activity programs, the focus of which is most appropriate for representatives of a particular somatotype due to its genetically determined capabilities and abilities, and the load parameters are adequate to the current capabilities of each (Iedynak et al., 2021).

However, so far, the data in this area are insufficient to successfully solve this problem. In addition, there are few studies on the peculiarities of manifestation, which mark the components of functional and motor fitness of with different somatotypes, primarily taking into account the influence of such an external factor as the absence or minimization of physical activity at the university. All of the above has led to the conduct of the study on the chosen topic.

Materials and Methods

Study Participants

The study involved 39, each aged 17.6 ± 0.5 years. They belonged to different somatotypes, but none of them had reservations about using different parameters of physical activity. The distribution of these by somatotype was as follows: 8 belonged to the asthenic somatotype (A-type), 12 to the thoracic somatotype (T-type), 10 to the muscular somatotype (M-type), and 9 to the digestive somatotype (D-type).

Variables and Criterion Measures

Eleven (11) essential fitness indicators were the focus of the study. The motor tests recommended by the researchers were used (Tab. 1).

Table 1. Variables and criterion measures

Variables	Test items	Unit of measure
Agility	4 × 9 m SR	Second (s)
Leg balance	SLB/ Flamingo Balance test	Number of attempts (n)
Speed of individual movement	20 m S	Second (s)
Speed of limb movement	10 s PTT	Number (n)
Power (legs) (arms)	SBJ SMBT	Centimeter (cm) Meter (m)
Arm muscle strength	max. FE	Number (n)
Abdominal muscle strength	60 s. SU	Number (n)
Back muscle strength	BE/Static dynamometry	Kilogram (kg)
Flexibility	SAR	Centimeter (cm)
Cardiovascular endurance	Cooper/12 minutes run	Meter (m)

*SR= Shuttle Run, SLB= single leg balance, S= sprint, PTT= Plate tapping test, SBJ= Standing Broad Jump, SMBT = seated medicine ball throw, FE= Flexion-extension, SU= Sit-up, BE= Back extension, SAR= Sit-and-Reach

Each of these tests is well known to researchers, is widely used in physical activity practice, and meets the requirements of reliability and informativeness (Bhagi et al., 2024; Eurofit Fitness Testing Battery, 2025; Fitness tests, 2025).

Test Procedure

SR test was conducted in a gym. Two lines were located on the running course at a distance of 9 meters from each other. Each line had one cone that the young man had to run around. One of the lines was marked as the start and finish. Here, each young man took a high start position, and on the coach's command, he started running at maximum speed to the cone opposite. After that, the young man ran around this cone and started moving in the opposite direction to another cone. In total, he had to overcome 4 segments. The result was the time to overcome these segments, for which the young man was given one attempt. The SLB test was performed according to the recommendations of the Eurofit Fitness Testing Battery (2025). The S-test was performed on an athletic treadmill, with a total distance of 30 meters. There were three lines on the treadmill: from the first line (start) to the second (intermediate line) the distance was 10 meters, and from the second line to the third (finish) – 20 meters. Before starting to run, the young man on the start line took a high start position. He started to move only with the permission of the coach (shot of the starting pistol) and covered the distance using a straight run at maximum speed. The test was conducted twice, and the best result was taken into account with an accuracy of 0.1 seconds. Determining the time it took to cover the 20-meter distance had its peculiarity. The stopwatch was turned on when the young man crossed the second line and turned off when he crossed the third line, i.e. the finish line. At the same time, the distance of 10 meters (between the first and second lines) was intended to allow

the young man to gain maximum speed and to eliminate the influence on the result of the time spent by the young man on the reaction he showed after the coach's permission to start moving. The PTT test was used to study the state of development of young men' hand speed. The test involved a young man performing the maximum possible number of taps with a pencil on the surface of a clean sheet of paper on the table in 10 seconds. After completing the task, the number of dots that the young man managed to put on the paper was counted. The organization of the test included the following: the table was adjustable, it was adjusted so that the young man could sit comfortably at it and place his hand with a pencil on it; during the test, the hand holding the pencil could not be taken off the table surface; two attempts were given, the best result was taken into account. SBJ-test was used to assess the strength and power of the lower extremities. The young man stood with his heels on a line, then jumped horizontally as far as possible without specific instructions on leg or arm movements. After landing with both feet together, the jump distance was measured from the starting line to the heel closest to the start. The SMBT test was used to assess upper limb strength and power. The young man sat on the line so that it and his back formed the same plane, and his feet were positioned in the throwing sector. His arms were placed behind his head with a one-kilogram ball. After the coach's permission, the young man threw the ball as far as possible with both hands without specific instructions on such movements. The FE test allowed us to evaluate the strength endurance of the arm muscles in a dynamic mode of operation. The young man performed flexion and extension of the arms in a handstand on the floor. The arms were shoulder-width apart, not bent at the elbow joints, the legs touched each other, not bent at the knee joints. The movement is scored when the young man touches the floor with his chest while bending his arms and then returns to the starting position. The maximum number of movements was evaluated. The SU-test also allowed us to evaluate strength endurance, but only of the abdominal muscles in a dynamic mode of operation. The young man begins by lying on his back with his knees bent at a 90-degree angle. The young man's hands should be placed behind his head and his elbows extended straight ahead. The number of repetitions of the movement within one minute is estimated. BE-test allowed us to assess the state of development of isometric strength of the musculus erector spinae. The test involves the use of a special device, we used PSH-1000N and took into account the recommendations of researchers (Yu et al., 2023). The result of the SAR test was used to determine the flexibility of the young man. This test was performed in accordance with the recommendations of the Eurofit Fitness Testing Battery (2025). The Cooper test was used to assess the aerobic capacity and cardiovascular system of a young man.

Study Organization

Somatotypes were diagnosed at the beginning of the experiment. The use of this scheme was due to the following reasons: the main characteristics of the scheme are very similar to the Heath-Carter scheme, which is most often used by researchers from Europe and the United States (Carter, & Heath, 1990; Bertuccioli et al., 2022; Campa, & Greco, 2022). The modified methodology of the Shtefko-Ostrovsky scheme

makes it extremely possible to establish a certain trend, especially manifestations and changes in motor fitness in comparison with the data of other researchers (Sands, 2012; Iedynak et al., 2021; Silventoinen et al., 2021). Testing was conducted at the beginning (January) and end (May-June) of the academic semester during one academic year. The results were compared with each other first in each somatotype, then in different somatypes. The increase or decrease in the parameters of a certain component of motor fitness or its manifestation at the previously achieved level was determined.

The study was planned and implemented by the principles of bioethics set out by the World Medical Association (WMA-2013).

Statistical Analysis

All statistical analyses were performed using SPSS Version 21. For each indicator of motor fitness, we determined: arithmetic mean (M), standard deviation (SD), minimum (Min) and maximum (Max) values. To check the normality of the data in each sample of, the Kolmogorov-Smirnov Test (KS) was conducted; it confirmed that the data corresponded to a normal distribution. This allowed us to use the t-test for related and unrelated samples when comparing two means (significance levels of 0.05, 0.01, 0.001). The F-test was also used to determine the relative variance when comparing two means in independent samples (Weir & Vincent, 2020).

Results

Before studying the empirical data, we analyzed them from the point of view of compliance with the normal distribution of values of each physiological characteristic in the studied samples. The K-S Test was used, and the results in all cases revealed a normal distribution of values (Tab. 2).

When comparing the data of young men with different somatypes, the existence of differences in the achieved parameters was revealed. Thus, the largest number of statistically significant differences was in the pair of samples of D- and T- types, namely 10 out of all 11 components of motor fitness (Tab. 3).

The D-type had better results in SMBT and BE, and the T-type had better results in all other components.

In a pair of samples of D- and M-types, the parameters of 9 components differed, but only in SAR did D-type young men have an advantage.

In A- and D-types a statistically significant difference of parameters was found in 7 of all 11 components of motor fitness. But in 2 components (SMBT and BE) the D-type was marked by the best parameters, while in the other (S, SBJ, FE, SR, SLB) – A-type.

Continuing to compare the achievements of young men with A-type and representatives of other somatypes, it was found that they and with M-type differed in the parameters of 8 components. Of these, young men with A-type had better results in Cooper test and SLB, and young men with M-type – in S, SBJ, SMBT, BE, FE and SU.

The results of the A- and T-types differed in 7 indicators, but the former had the best SLB parameters, the latter – S, SBJ, SMBT, BE, FE and SR.

As for the T- and M-types, the smallest number of results were found differed by a statistically significant amount when compared; there were 5 out of all 11 indicators.

Table 2. Results of young men with different somatotypes at the beginning of the study

N	Name of the test	M1	SD	Min	Max	K-S, p
A-type (n=8)						
1	S	3.28	0.24	3.00	3.60	>0.20
2	PTT	68.13	4.19	60.00	73.00	>0.20
3	SBJ	190.63	8.03	175.00	200.00	>0.20
4	SMBT	4.96	0.49	4.20	5.60	>0.20
5	BE	71.75	8.48	60.00	81.00	>0.10
6	FE	17.25	4.59	10.00	24.00	>0.20
7	SU	38.13	6.17	30.00	47.00	>0.20
8	SAR	6.23	2.23	3.20	8.90	>0.20
9	SR	10.93	0.66	10.10	11.80	>0.20
10	Cooper-test	2362.50	188.05	2150.00	2680.00	>0.20
11	SLB	4.25	2.05	2.00	8.00	>0.20
T-type (n=12)						
1	S	2.90	0.31	2.50	3.40	>0.20
2	PTT	71.08	4.06	64.00	79.00	>0.20
3	SBJ	217.08	9.53	195.00	230.00	>0.20
4	SMBT	6.18	0.54	5.40	7.20	>0.20
5	BE	86.46	9.10	72.00	104.00	>0.20
6	FE	23.42	5.60	15.00	35.00	>0.20
7	SU	41.75	5.82	29.00	50.00	>0.10
8	SAR	7.88	2.78	4.40	12.50	>0.20
9	SR	10.11	0.39	9.50	10.80	>0.20
10	Cooper-test	2274.17	238.84	1920.00	2550.00	>0.20
11	SLB	6.67	2.74	3.00	11.00	>0.20
M-type (n=10)						
1	S	3.00	0.27	2.60	3.40	>0.20
2	PTT	65.70	4.67	57.00	71.00	>0.20
3	SBJ	210.30	8.41	197.00	224.00	>0.20
4	SMBT	6.970	0.43	6.30	7.50	>0.20
5	BE	96.50	9.31	83.00	115.00	>0.20
6	FE	30.10	6.51	20.00	42.00	>0.20
7	SU	48.30	6.13	40.00	59.00	>0.20
8	SAR	6.98	2.18	3.10	9.40	>0.20
9	SR	10.01	0.41	9.40	10.70	>0.20
10	Cooper-test	2144.00	153.13	1950.00	2350.00	>0.20
11	SLB	7.10	2.76	3.00	10.00	>0.20
D-type (n=9)						
1	S	3.61	0.26	3.30	4.10	>0.20
2	PTT	60.30	5.43	51.00	68.00	>0.20
3	SBJ	171.89	9.06	156.00	183.00	>0.20
4	SMBT	7.00	0.63	6.00	7.90	>0.20
5	BE	98.56	6.69	91.00	110.00	>0.10
6	FE	10.78	3.31	5.00	15.00	>0.20
7	SU	27.11	5.33	18.00	34.00	>0.20
8	SAR	10.33	2.92	7.00	15.00	>0.20
9	SR	11.22	0.40	10.70	11.80	>0.20
10	Cooper-test	1785.56	150.01	1500.00	1950.00	>0.20
11	SLB	9.89	1.96	6.00	12.00	>0.20

Note: SR = Shuttle Run, SLB = single leg balance, S = sprint, PTT = Plate tapping test, SBJ = Standing Broad Jump, SMBT = seated medicine ball throw, FE = Flexion-extension, SU = Sit-up, BE = Back extension, SAR = Sit-and-Reach

The repeated study, which took place at the end of the academic year, revealed certain features of changes in the parameters of the studied components of motor fitness. One of them is a change in parameters of only certain components in each somatotype. However, in young men with D-type changes were not statistically significant, that is they showed only a certain tendency (Tab. 4).

In young men with A-, T- and M- types, only SU parameters showed a statistically significant change. However, the first ones indicated a deterioration in the development of this component of motor fitness.

The changes detected at the end of the school year indicated an increase in the discrepancies between the parameters of young men with a certain somatotype. Thus, in A- and T-types, the number of indicators with significant differences in parameters increased from 7 at the beginning to 9 at the end of the study (Tab. 5).

Comparison of A- and M-types revealed that the results of 8 of all 11 components differed, i.e., at the beginning of the study. But if at the beginning the state of development of speed qualities differed, then at the end it disappeared: the result of young men with A-type was 3.21 ± 0.20 seconds, young men with M-type – 2.9 ± 0.31 ($t = 0.334$; $p > 0.05$). There was a difference in the development of flexibility, and at the beginning of the study, there was none: in A-type the result was 6.38 ± 1.9 centimeters, in M-type – 7.4 ± 2.79 centimeters ($t = 3.524$; $p < 0.01$); the latter result was better. In the other 7 components, the pattern of discrepancy remained the same as at the beginning of the study.

In the pair of samples D-A, there was a significant increase (from 7 at the beginning to 10 at the end of the study) in the number of components with different results. PTT, SU, SAR, and Cooper-test were added to the components identified at the beginning of the study. The results in all but SAR were better in the A-type; in young men with D-type, SAR parameters were at the level of 11.0 ± 3.67 centimeters, in young men with A-type – only 6.38 ± 1.9 centimeters ($t = -3.193$; $p < 0.01$).

Comparison of results in D- and T-types at the end of the study showed that the number of components of motor fitness, the results of which differed from each other, was 10 out of all 11.

In the pair of samples D-M, at the end of the study, the number of components with statistically significant differences in parameters decreased from 9 to 7. These two components were PTT and SLB because the results of the young men of both samples in each component were almost identical. In the other 7 components, the peculiarity of the divergence of parameters was similar to that found at the beginning of the study.

Comparison of results in T- and M-types at the end of the research showed that the number of components of motor fitness, the results of which differed from each other, was the same as established at the beginning of the research, namely 5 out of all 11. But the composition of these components partially differed.

Discussion

One of the important tasks of modern physical education is to identify the peculiarities in the development of students' motor fitness components, considering their somatotypes and the influence of such an external factor as the lack of compulsory physical activity at the university (Coulter et al.,

Table 3. Differences in results of young men with different somatotypes at the beginning of the study

Result (points)	The name of the component										
	1	2	3	4	5	6	7	8	9	10	11
A - T											
t	2.870	-1.577	-6.457	-5.108	-3.477	-2.583	-1.333	-1.407	3.493	0.878	-2.121
F	2.000	1.000	1.000	1.000	1.000	1.000	1.000	2.000	3.000	2.000	2.000
p	0.010	0.132	0.000	0.000	0.003	0.019	0.199	0.176	0.003	0.392	0.048
A - M											
t	2.870	1.145	-5.030	-9.263	-7.278	3.365	3.951	-3.229	-1.138	7.033	-2.474
F	1.300	1.200	1.100	1.300	1.600	1.900	1.300	1.700	2.800	1.600	1.700
p	0.037	0.269	0.000	0.000	0.000	0.004	0.001	0.006	0.273	0.000	0.025
A - D											
t	-2.787	3.278	4.485	-7.383	-3.477	-2.583	-1.333	-1.407	3.493	0.878	-5.784
F	1.200	1.700	1.300	1.600	1.000	1.000	1.000	2.000	3.000	2.000	1.100
p	0.014	0.005	0.000	0.000	0.003	0.019	0.199	0.176	0.003	0.392	0.000
T - M											
t	-0.796	2.896	1.752	-3.720	-2.441	-2.591	-2.567	0.834	0.576	1.485	-0.373
F	1.400	1.300	1.300	1.600	1.000	1.300	1.100	1.600	1.100	2.400	1.000
p	0.435	0.009	0.095	0.001	0.025	0.018	0.018	0.414	0.571	0.153	0.713
T - D											
t	-5.542	5.204	10.979	-3.197	-3.214	6.008	5.912	-1.957	-6.461	5.375	-2.989
F	1.500	1.800	1.100	1.300	2.000	2.900	1.200	1.100	1.000	2.500	1.900
p	0.000	0.000	0.000	0.005	0.005	0.000	0.000	0.065	0.000	0.000	0.008
M - D											
t	-5.072	2.317	9.586	-0.123	-0.547	8.011	-7.999	-2.858	-6.519	5.144	-2.557
F	1.100	1.400	1.200	2.200	1.900	3.900	1.300	1.800	1.100	1.000	1.900
p	0.000	0.033	0.000	0.904	0.592	0.000	0.000	0.011	0.000	0.000	0.020

*Note: a reliably significant difference between the two means is highlighted in color

2016; Andrieieva et al., 2023). In this regard, researchers are increasingly paying attention to the problem of personalization of university physical education based on offering each student their own educational trajectory (Frąckiewicz, 2023).

The use of such a marker as somatotype is promising in solving this problem of university physical education (Cinarli et al., 2019; Campa, 2022). This conclusion is confirmed by the data obtained at the beginning of the study. In the samples created taking into account the somatotypes of, the distribution of individual results in the components of motor fitness corresponded to the normal one. A similar conclusion was reached in another study (Banakh et al., 2023). One of the reasons for this trend is the lack of polymodality, that is, the combination of two or more qualitatively different populations in one sample, even with the same other characteristics (Weir, & Vincent, 2020). When studying the functional, motor, and morphological characteristics of children and youth of a certain gender and age, there is a rather high polymodality. This is evidenced by a different from normal distribution of individual results in the studied characteristic. However, polymodality is much less or even disappears if not only gender and age are taken into account when forming a sample, but also belonging to a certain somatotype (Iedynak et al., 2021).

In addition, at the beginning of the study, data were obtained that showed significant differences in the results of different somatotypes in all components of motor fitness. The obtained data reflected the scientific position that each somatotype is characterized by features that relate to the reactivity of the organism, style of activity, rate of individual development and prerequisites of the individual's abilities (Silventoinen et al., 2021). Also, researchers (Wilmore et al., 2022) note the unequal rate of development of different functional systems, differences in the parameters of physiological characteristics and components of motor fitness of young men and girls with different somatotypes.

At the end of the research, the increase of differences in results of young men different somatotypes and very insignificant changes in components of their motor fitness was revealed. Such data confirmed the above information and were caused by a complex of reasons. One of the main ones was the lack of compulsory physical activity for students at the university, first in connection with Covid-19, and later – in connection with air raids due to the war. This lack of compulsory physical education classes could have led to a decrease in physical activity among, which is confirmed by the results of other researchers (Andrieieva et al., 2023). The above also

Table 4. Results of young men with different somatotypes at the end of the study and the statistical reliability of their change

N	The name of the component	M2	SD	Min	Max	(M1 – M2)	
						t	p
A-type (n=12)							
1	S	3.21	0.20	3.00	3.50	1.174	0.279
2	PTT	68.13	4.08	61.00	73.00	0	1.000
3	SBJ	191.38	6.37	179.00	197.00	-0.767	0.468
4	SMBT	5.00	0.44	4.50	5.50	-0.814	0.442
5	BE	73.50	8.00	63.00	83.00	-1.862	0.060
6	FE	18.00	3.78	12.00	23.00	-1.655	0.142
7	SU	39.38	5.10	33.00	47.00	-3.035	0.019
8	SAR	6.38	1.90	4.00	8.70	-1.111	0.303
9	SR	10.88	0.51	10.20	11.70	0.764	0.470
10	Cooper-test	2402.50	130.14	2280.00	2670.00	-1.586	0.157
11	SLB	4.13	2.10	1.00	7.00	0.314	0.763
T-type (n=22)							
1	S	2.90	0.31	2.50	3.40	0.000	1.000
2	PTT	71.58	3.03	67.00	79.00	-0.342	0.735
3	SBJ	218.17	9.73	194.00	229.00	-2.066	0.785
4	SMBT	6.31	0.73	5.50	7.80	-0.476	0.638
5	BE	87.92	10.76	76.00	108.00	-0.344	0.734
6	FE	24.30	5.82	14.00	37.00	-0.393	0.698
7	SU	47.42	7.43	31.00	60.00	-2.281	0.049
8	SAR	8.16	3.71	2.60	15.80	-0.205	0.839
9	SR	10.07	0.38	9.30	10.70	0.265	0.793
10	Cooper-test	2236.67	224.80	1980.00	2610.00	0.396	0.696
11	SLB	7.00	2.79	2.00	10.00	0.000	1.000
M-type (n=22)							
1	S	3.19	0.20	2.80	3.40	-0.504	0.611
2	PTT	65.90	4.72	58.00	72.00	-0.095	0.925
3	SBJ	208.60	10.54	195.00	227.00	0.399	0.695
4	SMBT	7.02	0.50	6.30	7.70	-0.242	0.812
5	BE	96.50	10.89	85.00	121.00	0.000	1.000
6	FE	31.60	6.65	23.00	45.00	-0.510	0.616
7	SU	53.50	6.69	45.00	66.00	5.838	0.000
8	SAR	6.90	2.49	2.90	9.60	0.077	0.940
9	SR	10.01	0.52	9.30	10.70	-0.000	1.000
10	Cooper-test	2077.00	223.56	1900.00	2440.00	0.782	0.444
11	SLB	7.40	2.01	4.00	10.00	-0.283	0.781
D-type (n=10)							
1	S	3.66	0.36	3.30	4.40	-0.299	0.769
2	PTT	61.11	6.51	52.00	70.00	-0.275	0.787
3	SBJ	170.22	9.56	153.00	184.00	0.380	0.709
4	SMBT	7.07	0.71	5.90	7.90	-0.211	0.835
5	BE	98.67	8.25	88.00	114.00	-0.031	0.975
6	FE	10.00	3.43	5.00	15.00	0.490	0.631
7	SU	26.22	6.28	16.00	35.00	0.324	0.750
8	SAR	11.00	3.67	6.00	16.00	-0.426	0.675
9	SR	11.13	0.37	10.70	11.80	0.491	0.630
10	Cooper-test	1750.00	160.78	1750.00	1980.00	0.485	0.634
11	SLB	9.22	1.86	6.00	11.00	0.740	0.470

Note: SR = Shuttle Run, SLB = single leg balance, S = sprint, PTT = Plate tapping test, SBJ = Standing Broad Jump, SMBT = seated medicine ball throw, FE= Flexion-extension, SU= Sit-up, BE= Back extension, SAR= Sit-and-Reach. A reliably significant difference between the two means is highlighted in color

Table 5. Differences in results of young men with different somatotypes at the end of the study

Result (points)	The name of the component										
	1	2	3	4	5	6	7	8	9	10	11
A - T											
t	2.483	-2.178	-6.840	-4.536	-3.230	-2.708	-2.662	-1.246	4.038	1.877	-2.126
F	2.000	2.000	2.000	3.000	2.000	2.000	2.000	4.000	2.000	3.000	2.000
p	0.023	0.043	0.000	0.000	0.005	0.014	0.019	0.229	0.001	0.077	0.048
A - M											
t	0.234	1.053	-4.053	-9.033	-4.984	-5.137	-4.927	-0.492	3.524	3.641	-3.367
F	1.000	1.000	3.000	1.000	2.000	3.000	2.000	2.000	1.000	3.000	1.000
p	0.818	0.308	0.001	0.0000	0.000	0.000	0.000	0.629	0.003	0.002	0.039
A - D											
t	-3.038	2.619	5.291	-7.115	-6.369	4.578	4.700	-3.193	-1.198	9.118	-5.315
F	3.200	2.500	2.300	2.600	1.100	1.200	1.500	3.700	1.900	1.500	1.300
p	0.008	0.019	0.000	0.000	0.000	0.000	0.003	0.006	0.025	0.000	0.000
T - M											
t	-2.516	3.417	2.211	-2.617	-1.854	-2.733	-2.000	0.913	0.295	1.663	-0.674
F	2.000	2.000	1.000	2.000	1.000	1.000	1.000	2.000	2.000	1.000	2.000
p	0.021	0.003	0.039	0.017	0.079	0.013	0.059	0.037	0.771	0.112	0.508
T - D											
t	-5.103	4.936	11.255	-2.386	-2.493	6.559	6.898	-1.743	-6.409	5.509	-2.304
F	1.400	4.600	1.000	1.100	1.700	2.900	1.400	1.000	1.100	2.000	2.400
p	0.000	0.000	0.000	0.028	0.022	0.000	0.000	0.097	0.000	0.000	0.033
M - D											
t	-3.492	1.850	8.275	-0.168	-0.485	8.735	9.135	-2.876	-5.366	3.621	-2.045
F	3.200	1.900	1.200	2.000	1.700	3.800	1.100	2.200	2.000	1.900	1.200
p	0.003	0.082	0.000	0.869	0.634	0.000	0.000	0.011	0.000	0.002	0.057

leads to another result, in particular, a clear negative impact on the psychological characteristics of students (Limone et al., 2022; Byshevets et al., 2024) and their functional characteristics (Banakh et al., 2023). This study revealed the negative impact of these factors (COVID-19 and the Russian-Ukrainian war) on the development of the components of motor fitness of during their studies at university (Mykityuk et al., 2022).

Conclusions

First-year young men with different somatotypes are marked by peculiarities in the development of motor fitness components. At the beginning of the research the most (10) differences (reliability within $p < 0.05 \div 0.0000$) of all 11 components were found in a pair of samples T-D. In the other pairs, the number is as follows: D-M – 9, M-A – 8, T-M – 5, D-A and A-T – 7, but unequal components. At the end of the study, the differences increased somewhat: the number of components with different results in the D-A sample pair reached 10 out of all 11 subjects, in the A-T sample pair – 9; the number remained the same, but with some changes in the components themselves, in A-M (8) and T-M (5); the number decreased to 7 in the D-M sample pair.

A general trend in the change in the results of A-, T-, and M-types was established: the SU results changed by a statistically significant amount, but in the first sample the change was negative, in the other two samples – positive. The D-type was characterized by the absence of components in which the change in results was statistically significant.

Such data should be considered during physical education classes for students, as well as used in the development

of personal programs for their physical activity in their free time.

Conflicts of Interest

No conflicts of interest exist.

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З'ясування відмінностей у прояві компонентів рухової підготовленості юнаків за відсутності обов'язкової фізичної активності

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

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Сучасна тенденція в модернізації університетського фізичного виховання передбачає розроблення кожному студенту персональної освітньої траєкторії.

Мета статті – визначити особливості в розвитку компонентів рухової підготовленості юнаків при врахуванні їх соматотипів і відсутності в університеті обов'язкової фізичної активності.

Матеріали та методи. У дослідженні взяли участь 39 юнаків 17,6±0,5 років, які тільки розпочали навчання в університеті, належали до різних соматотипів та не мали обмежень у використанні різних параметрів фізичної активності. Соматотип визначали за допомогою модифікованої методики Штефко-Островського. Вивчали 11 основних компонентів рухової підготовленості, використовували рекомендовані дослідниками рухові тести, відповідні методи тестування та інструменти. Кожний тест відповідав вимогам надійності, інформативності та дозволяв оцінити швидкість, частоту рухів, здатність до рівноваги, абсолютну м'язову силу, вибухову силу рук і ніг, динамічну силу м'язів живота і рук, гнучкість, спритність, аеробну витривалість. Параметри цих компонентів визначали у юнаків кожного наявного соматотипу, а також порівнювали кожний параметр у різних соматотипах. Тестування проводили на початку (січень) та наприкінці (травень-червень) навчального семестру, але протягом одного навчального року.

Результати. На початку та наприкінці дослідження розвиток компонентів рухової підготовленості у кожному соматотипі відрізнявся при порівнянні між собою (p на рівні від 0.05 до 0.000). Використані протягом дослідження обсяги та умови реалізації фізичної активності сприяли зміні результатів юнаків у деяких компонентах, але ці зміни були неоднаковими у різних соматотипах.

Висновки. Інформація про особливості розвитку компонентів рухової підготовленості юнаків із різними соматотипами є важливою для підвищення дієвості університетського фізичного виховання на засадах персоналізації змістової і диференціації нормативної основ цього процесу.

Ключові слова: рухова підготовленість, юнаки, соматотипи, персоналізація, університетське фізичне виховання, фізична активність, Covid-19.

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Determining the Effect of Core Strength Training on Dynamic Balance, Flexibility and Footwork Skill of Badminton Players

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Abstract

Background. Badminton is a technical racket sport that requires intense and explosive movements, with performance dependent on factors such as balance, agility, and core strength. Previous research has emphasized the significance of core fitness in fostering stability and dynamic balance for performance and injury prevention. However, its effects on badminton-specific skills remain relatively underexplored.

Objectives. This study aimed to investigate the impact of core strength training on dynamic balance, flexibility, and footwork skills among badminton players.

Materials and methods. Thirty male intercollegiate badminton players, aged 20-25, were randomly divided into experimental (n = 15) and control (n = 15) groups. Over 12 weeks, the experimental group underwent core strength training, while the control group maintained their regular routine. Pre- and post-test data were collected using the Y-balance test for dynamic balance, sit and reach test for flexibility, and Hick's footwork skill test for proficiency.

Results. Statistical analysis using paired t-tests and ANCOVA revealed significant improvements in the experimental group across all measured parameters, including dynamic balance (anterior, posteromedial, and posterolateral reaches), flexibility, and footwork skills. Conversely, the control group exhibited no substantial changes.

Conclusions. These findings underscore the efficacy of core strength training in enhancing essential physical attributes that are critical for badminton performance.

Keywords: dynamic balance, flexibility, footwork skills, badminton players, sports performance, physical fitness, athletic training, injury prevention.

Introduction

Badminton is one of the most popular racket sports all over the world. It is a technical racket sport characterised by intense and explosive short movements around the court (Ahmed, Saraswat, & Esht, 2022). The popularity and participation have grown ever since its inclusion to 1992 Olympic Games. It is a complex sport whose performance depends on different factors such as anthropometry, physiology, motor fitness, etc. (Phomsoupha & Laffaye, 2015). Badminton requires good balance and agility; better

balance and agility enables a player to move well and quicker around the court and enables a player to give best performance during a match, (Singh, Raza, & Mohammad, 2011). Mohammadi & Fathi (2018) explained better core fitness level improves the stability and dynamic balance of the body. Which indicates that to enhance badminton performance, there is need to improve motor fitness and core strength improvement will enhance stability.

Previous investigations highlighted the importance of different training methods for the improvement of fitness and badminton performance (Kuo, Liao, & Kao, 2022; Malwanage, Senadheera, & Dassanayake, 2022; Panda et al., 2022). Different form of training shows different level and aspects of improvement in motor fitness as well as performance of badminton players. It is important for

coaches and players to adopt appropriate form of training understanding their strength and weakness of the game. As competitive badminton matches last from 40 minutes to 1 hour, players need to maintain higher intensity and execute perfect rallies for longer period of time to have desirable outcome of the game (Phomsoupha & Laffaye, 2015). Ozmen & Aydogmus (2016) explained that core improvement can enhance dynamic balance of adolescent badminton players.

In last few decades, people are getting to understand the importance of core fitness in sport training, performance and injury prevention (Mohammadi & Fathi, 2018). The core muscles of the body stabilize the movement of the upper and lower extremities. Strong core muscles create movement in both the upper and lower bodies efficiently. Core strength in badminton is one of the most fundamental attributes any players should have. It acts to stabilize the body and generate force and act as a kinetic chain for energy transference. A core muscle is used during dynamic activity to support the thorax and pelvis and to create internal pressure for material excretion. Engaging in core strength training can help to decrease and avoid lower and knee joint issues (Churi & Varadharajulu, 2020, Beniwal & Dhauta, 2021). It is very important to train or strengthen the core much as strong core muscle could improve balance and stability, make movement easier and controlled, prevent injury, maintenance of energy system, or controls of movements and also to increase core strength and endurance to improve sports performance and to reduce injury risk (Beniwal & Dhauta, 2021; Shukla, 2022; Behm, Leonard, Young, Bonsey, & MacKinnon, 2005).

While several studies have highlighted the benefits of core training on various physical aspects (Wang & Cheng, 2017). There is a need for targeted research on how core strength training specifically affects dynamic balance, flexibility, and footwork skills in badminton players. This study aims to fill this gap by examining the impact of a structured core strength training program on these critical performance parameters in male badminton players.

Materials and Methods

Participants

After obtaining consent, 30 male badminton players, aged between 20 to 25 years, were selected for this study using purposive sampling from colleges affiliated with Manipur University. All participants had previously competed in inter-collegiate badminton tournaments and represent national level tournament. They were divided into two groups: an Experimental Group (15 subjects) and a Control Group (15 subjects). None of the subjects had undergone any formal training in the past five months, although they continued to play badminton regularly. Pre-test data were collected for both groups using specified assessment tests before the commencement of the training program. The Experimental Group then underwent a core strength training regimen

for 12 weeks, while the Control Group did not receive any specialized training. After the 12-week period, post-test data were collected from both groups to assess the impact of the core strength training on dynamic balance, flexibility, and footwork skills.

Core Training

The core training was given to the experimental group and they were also allowed to play badminton after or later training. The control group was not implemented with any form of training, they continue playing their regular badminton. The training of core strength was given at Manipur University campus and was conducted in morning for 3 days per week for 12 weeks. The core training exercises include; isometric v-up, Bird Dog, Front plank, Side Plank, Superman, Sit ups Russian Twist, Leg Raise, Reverse Crunches and Kneeling Wheel Roll-Out. The training was conducted in three phases 1-4 weeks (10reps /3sets), 5-8 weeks (12reps/3sets) and 9-12 weeks (15reps/3sets).

Statistical Analysis

The data pertaining the study was examined statistically by using IBM SPSS 21 version software. Shapiro-Wilk normality test was used to check the data normality of the selected parameters. The descriptive analysis of the data was conducted and to compare means, pair sample t-test and Analysis of Covariance (ANCOVA) was used. The level of significance is set at 0.05.

Results

The age of the subjects was 22.60 ± 1.76 for experimental group and 22.06 ± 1.53 for control group. Likewise, 68 ± 10.63 and 66 ± 7.44 were the weight of experimental and control group respectively. The height and BMI of experimental and control group were 5.12 ± 0.24 , 23.65 ± 2.03 and 22 ± 1.53 , 23.63 ± 2.96 respectively as shown in Table1. There was not much difference in the demographic characteristics of the subjects of both the groups.

From Table 2, we can see that there was normal distribution in most parameters of both control and experimental group excluding, RPM (Dynamic balance) of Experimental group and footwork skill of control group.

The mean and standard deviation, as shown in Table 3, of the dynamic balance; LA, LPL, LPM, RA, RPL, RPM, Footwork and Flexibility of pre-test are 68.20 ± 3.48 , 75.93 ± 7.41 , 81.46 ± 5.18 , 67.46 ± 4.56 , 75.53 ± 8.03 , 80.40 ± 7.50 , 9.13 ± 0.74 and 30.40 ± 4.71 . The mean and standard deviation of dynamic balance; LA, LPL, LPM, RA, RPL, RPM, Footwork and Flexibility of post-test are 72.13 ± 3.15 , 79.60 ± 7.61 , 84.60 ± 4.33 , 72.13 ± 3.15 , 80.40 ± 7.39 , 83.26 ± 7.07 , 9.66 ± 0.61 and 33.53 ± 4.45 respectively. There was significant difference found in

Table 1. Demographic characteristics of the participants

GROUP	AGE (Year)	WEIGHT (Kg)	HEIGHT (Feet)	BMI (Kg/m ²)
Experimental	22.60 ± 1.76	68 ± 10.63	5.12 ± 0.24	23.65 ± 2.03
Control	22.06 ± 1.53	66 ± 7.44	5.06 ± 0.01	23.63 ± 2.96

dynamic balance as t value of LA, LPL, LPM, RA, RPL and RPM are respectively 12.458, 9.811, 7.596, 4.167, 7.999 and 5.776 which are higher than table t = 2.045. There was significant difference found for footwork and flexibility also as calculated t are respectively 4.000 and 13.256 which are

much higher than table t = 2.045. Therefore, there significant improvement found in experimental group. The graphical presentation of pre-test and post-test dynamic balance, flexibility and footwork skill are given in figure1 below.

Table 2. Normality test of the selected variables

Variable	Group	Mean	SD	Shapiro-Wilk	
				W	sig
LPL	CG	76.66	5.74	0.904	0.110
	EG	75.93	7.41	0.926	0.235
LPM	CG	79.06	5.67	0.882	0.051
	EG	81.46	5.18	0.991	1.00
LA	CG	64.46	3.02	0.906	0.120
	EG	68.20	3.48	0.926	0.236
RA	CG	65.26	4.11	0.913	0.153
	EG	67.46	4.56	0.941	0.395
RPL	CG	78.13	6.08	0.914	0.155
	EG	75.53	8.03	0.950	0.523
RPM	CG	80.20	4.72	0.940	0.377
	EG	80.40	7.50	0.843	0.014
Foot-work	CG	8.80	0.77	0.806	0.004
	EG	9.26	0.73	0.894	0.076
Flexibility	CG	32.80	3.66	0.936	0.338
	EG	30.40	4.71	0.947	0.482

LA: Left Anterior (Dynamic balance for the left leg in the anterior direction), LPL: Left Posterolateral (Dynamic balance for the left leg in the posterolateral direction), LPM: Left Posteromedial (Dynamic balance for the left leg in the posteromedial direction), RA: Right Anterior (Dynamic balance for the right leg in the anterior direction), RPL: Right Posterolateral (Dynamic balance for the right leg in the posterolateral direction), RPM: Right Posteromedial (Dynamic balance for the right leg in the posteromedial direction)

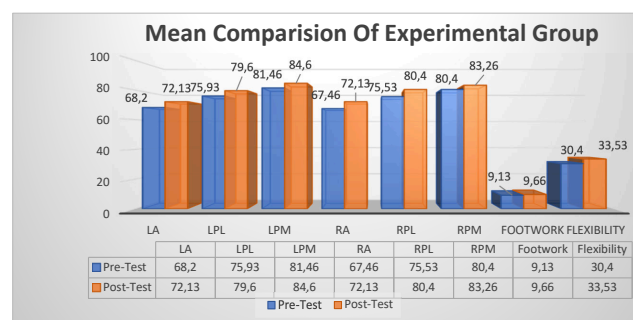


Fig. 1. Pre and post-test mean comparison of experimental group

From Table 4 we can see that the pre-test means and standard deviation of the dynamic balance; LA, LPL, LPM, RA, RPL, RPM, Footwork and Flexibility of pre-test are 64.46 ± 3.02 , 76.66 ± 5.74 , 79.06 ± 5.67 , 65.26 ± 4.11 , 78.13 ± 6.08 , 80.20 ± 4.72 , 8.80 ± 0.77 and 32.73 ± 3.69 . The

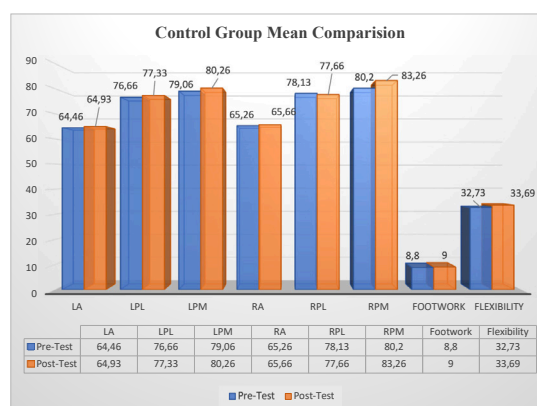


Fig. 2. Pre and post-test mean comparison of control group

Table 3. Descriptive statistics and t-test of experimental group

Variables	n	Mean		SD		Std. Error Mean	t
		Pre	Post	Pre	Post		
Dynamic Balance	LA	15	68.20	72.13	3.48	3.15	12.458
	LPL	15	75.93	79.60	7.41	7.61	9.811
	LPM	15	81.46	84.60	5.18	4.33	7.596
	RA	15	67.46	72.13	4.56	3.15	4.167
	RPL	15	75.53	80.40	8.03	7.39	7.999
	RPM	15	80.40	83.26	7.50	7.07	5.776
Footwork	15	9.13	9.66	0.74	0.61	0.13	4.000
Flexibility	15	30.40	33.53	4.71	4.45	0.23	13.256

*Significant at 0.05, $t=2.045$ LA: Left Anterior (Dynamic balance for the left leg in the anterior direction), LPL: Left Posterolateral (Dynamic balance for the left leg in the posterolateral direction), LPM: Left Posteromedial (Dynamic balance for the left leg in the posteromedial direction), RA: Right Anterior (Dynamic balance for the right leg in the anterior direction), RPL: Right Posterolateral (Dynamic balance for the right leg in the posterolateral direction), RPM: Right Posteromedial (Dynamic balance for the right leg in the posteromedial direction)

Table 4. Descriptive statistics and t-test of control group

Variables		n	Mean		SD		Std. Error Mean	t
			Pre	Post	Pre	Post		
Dynamic Balance	LA	15	64.46	64.93	3.02	3.39	1.28	0.363
	LPL	15	76.66	77.33	5.74	5.40	0.28	2.320
	LPM	15	79.06	80.26	5.67	5.04	1.94	0.619
	RA	15	65.26	65.66	4.11	3.65	1.21	0.328
	RPL	15	78.13	77.66	6.08	6.37	1.94	0.240
	RPM	15	80.20	83.26	4.72	7.07	1.50	2.035
Footwork		15	8.80	9.00	0.77	0.75	0.10	1.871
Flexibility		15	32.73	33.06	3.69	2.86	0.98	0.337

LA: Left Anterior (Dynamic balance for the left leg in the anterior direction), LPL: Left Posterolateral (Dynamic balance for the left leg in the posterolateral direction), LPM: Left Posteromedial (Dynamic balance for the left leg in the posteromedial direction), RA: Right Anterior (Dynamic balance for the right leg in the anterior direction), RPL: Right Posterolateral (Dynamic balance for the right leg in the posterolateral direction), RPM: Right Posteromedial (Dynamic balance for the right leg in the posteromedial direction)

Table 5. Pre and post mean comparison of experimental and control groups (ANCOVA)

Variables	Sources	Type III sum of squares	df	Mean Square	F	Sig. (P)
Dynamic Balance	LA Group	78.31	1	78.32	45.10	0.000
	LA Error	46.88	27	1.73		
	LA Total	141594.00	30			
	LPL Group	66.53	1	66.53	39.02	0.000
	LPL Error	46.02	27	1.70		
	LPL Total	185970.00	30			
	LPM Group	42.28	1	42.28	18.95	0.000
	LPM Error	60.22	27	2.23		
	LPM Total	204452.00	30			
	RA Group	194.96	1	194.96	30.81	0.000
	RA Error	170.82	27	6.32		
	RA Total	143057.00	30			
	RPL Group	145.50	1	145.50	51.53	0.000
	RPL Error	76.22	27	2.82		
	RPL Total	190084.00	30			
	RPM Group	36.96	1	36.96	14.71	0.001
	RPM Error	67.82	27	2.51		
	RPM Total	203048.00	30			
Footwork	Group	1.30	1	1.30	7.12	0.013
	Error	4.90	27	0.18		
	Total	2630.00	30			
Flexibility	Group	35.31	1	35.31	8.44	0.007
	Error	112.91	27	4.18		
	Total	33661.00	30			

*Significant at 0.05 level of confidence, where tabulated F (0.05) (1, 27) =4.21

post-test means and standard deviation of dynamic balance; LA, LPL, LPM, RA, RPL, RPM, Footwork and Flexibility of post-test are 64.93 ± 3.39 , 77.33 ± 5.40 , 80.26 ± 5.04 , 65.66 ± 3.65 , 77.66 ± 6.37 , 83.26 ± 7.07 , 9.00 ± 0.75 and 33.06 ± 2.86 respectively. For dynamic balance, there was insignificant difference found for LA, LPM, RA, RPL and RPM as calculated t value are respectively 0.363, 0.619, 0.328, 0.240 and 2.035 which are lower than table t = 2.045 whereas there was significant difference found for LPL as calculated t = 2.320 was higher than table t = 2.045. There

was insignificant difference found for footwork skill and flexibility as calculated t are respectively 1.871 and 0.337 are lower than table t = 2.045. The graphical presentation of pre-test and post-test dynamic balance, flexibility and footwork skill are given in figure 2.

It is evident from the findings of Table-V that there is significant improvement observed in dynamic balance; LA, LPL, LPM, RA, RPL and RPM between pre and post mean comparison between experimental and control groups as the observed F value; 45.10, 39.02, 18.95, 30.81, 51.53 and

14.71 respectively are much higher than table F value = 4.21 at 0.05 level of confidence and (1, 27) degree of freedom. There is significant difference found in footwork skill and flexibility of badminton players as calculated F value; 7.12 & 8.44 respectively are much higher than table F value = 4.21 at 0.05 level of confidence and (1, 27) degree of freedom.

Discussion

As per the findings of the study, it is understood that the selected dependent variables: dynamic balance, flexibility and footwork skill, showed significant improvement after 12 weeks of core strength training. The core muscles like any other muscle develops after conditioning and training. After 12 weeks of core strength training, it develops its strength, neural control of the muscles and enhance the neuromuscular efficiency.

Mengyao Xie (2016) stated that a more stable core muscles coordinate the upper extremities and lower extremities and regulates the energy system in various actions during the badminton game. Palekar, Nitin Savla, & Sangaonkar (2020) stated that there is positive correlation between core stability and agility in badminton players. As the training included exercises which aim in the development of core muscles and the training volume and intensity during the training, the core muscles develop its strength and therefore enhance its ability of the motor control of the upper and lower extremities. Body balance and stability depends mostly of the coordination of the upper and lower extremities, and after going through the full session of training the core muscles develops its strength. Hence, there was significant improvement found in dynamic balance which is an important fitness aspect for badminton players. Core fitness training is a form of training which helps in the development of core muscle efficiency which brings harmony in the functioning of the body increasing body stability which is important for any form of sports and activities. Many previous studies have showed the importance of proper core strength training for the improvement of balance (Jo et al., 2022; Salar et al., 2023; Bora & Dağlıoğlu, 2022). Simão et al. (2011) indicated that participation in strength training enhances the flexibility of the individuals. As the core muscles developed through core muscle training, the flexibility of badminton players increases. Malwanage et al. (2022) stated that improved stability enhances the footwork of badminton players. The improvement in core muscles enhance the performance of foot-work skill and as the muscle tone improved, the flexibility increases.

These findings are supported by another study of Hariprasad, Author, & Suthakar (2020). He studied the effects of core circuit stability training and periodised resistance circuit training on flexibility of collegiate male badminton players and found that the core stability circuit preparing enhanced Flexibility of inter collegiate male badminton players. Sighamoney, Kad, & Yeole (2018) studied the effect of core strengthening on dynamic balance and agility in badminton players and found that core strengthening significantly improves dynamic balance and ability of badminton players. In another study of Solanki & Gill (2021), it was found that core stability training improves smash stroke performance of various racket sports.

Conclusion

The study concludes that core strength training significantly enhances dynamic balance, flexibility, and footwork skills in

badminton players. The experimental group's marked improvements in these areas compared to the control group emphasize the critical role of core strength in sports performance. These findings promote the integration of core strength exercises into regular training programs to boost athletic performance and minimize the risk of injuries among badminton players.

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Conflict of Interest

The authors declared no conflict of interest.

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Визначення впливу силових тренувань м'язів кору на показники динамічної

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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., 2 рис., 22 джерела.

Історія питання. Бадмінтон — це технічний вид спорту з використанням ракетки, який потребує інтенсивних і вибухових рухів, а результативність гри залежить від певних факторів, як-от рівновага, спритність і сила м'язів кору. У попередніх дослідженнях наголошувалося на важливості тренуваності м'язів корпусу у розвитку стійкості та динамічної рівноваги для досягнення результативності та профілактики травматизму. Однак питання щодо впливу тренуваності м'язів кору на формування специфічних для бадмінтону навичок залишається відносно недостатньо вивченим.

Мета дослідження. Це дослідження мало на меті вивчити вплив силових тренувань м'язів кору на показники динамічної рівноваги, гнучкості та розвитку навичок роботи ніг серед гравців у бадмінтон.

Матеріали та методи. Тридцять чоловіків-бадмінтоністів міжвузівського рівня віком 20-25 років було розподілено за методом рандомізації на експериментальну (n=15) та контрольну (n=15) групи. Впродовж 12 тижнів експериментальна група проходила силові тренування м'язів кору, в той час як контрольна група дотримувалася свого звичайного режиму тренувань. Збір даних перед початком та після завершення тестування проводився за допомогою тесту на динамічну рівновагу ("Y-balance test"), тесту на гнучкість, що передбачає вимірювання загальної гнучкості тіла при згинанні тулуба вперед, сидючи на підлозі з витягнутими вперед руками ("Sit and reach test") та тесту Гіка з метою визначення рівня володіння навичками роботи ніг ("Hick's footwork skill test").

Результати. За результатами статистичного аналізу із застосуванням парних t-критеріїв та коваріаційного аналізу (ANCOVA) в експериментальній групі встановлено значне покращення за всіма вимірюваними параметрами, включаючи динамічну рівновагу (передній, задньомедіальний та задньолатеральний розмахи рухів), гнучкість та розвиток навичок роботи ніг. Натомість у контрольній групі суттєвих змін не спостерігалось.

Висновки. Отримані дані підкреслюють ефективність виконання силових тренувань м'язів кору щодо поліпшення основних фізичних якостей, що мають вирішальне значення для досягнення результативності в бадмінтоні.

Ключові слова: динамічна рівновага, гнучкість, навички роботи ніг, бадмінтоністи, спортивна результативність, фізична підготовленість, спортивне тренування, профілактика травматизму.

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Analyzing Emotional Control in University Athletes: A Cross-Cultural and Gender Perspective

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Abstract

Background. Emotional control plays a crucial role in athletic performance and is influenced by factors such as gender and cultural context. Understanding the interplay between emotional regulation and athletic success can provide valuable insights for optimizing performance strategies.

Objectives. This study aimed to investigate the role of emotional control in athletic performance among university athletes from Baghdad, Iraq, and Delhi, India, with a focus on examining differences by gender and university affiliation. It also examines the relationships between subscales of emotional control and overall performance.

Materials and methods. The study involved 300 athletes aged 18 to 30 years, equally divided between Baghdad University (BU), Iraq and Delhi University (DU), India, with balanced gender representation (75 male and 75 female athletes per university). Emotional control was assessed using the Emotional Control Questionnaire (ECQ), which includes subscales for rehearsal, emotional inhibition, aggression control, and benign control. Descriptive statistics, two-way ANOVA, and Pearson's correlations were employed for data analysis using SPSS software.

Results. Emotional control scores were comparable across both universities and genders, with BU athletes scoring slightly lower ($M = 34.41$, $SD = 5.86$) than DU athletes ($M = 34.66$, $SD = 3.46$). The two-way ANOVA revealed no significant differences in overall emotional control or its subscales due to gender, university affiliation, or their interaction, except for benign control, where DU athletes scored significantly higher ($F(1, 298) = 5.55$, $p = 0.02$). Strong positive correlations were identified between overall emotional control and the subscales of benign control ($r = .69$, $p < .01$), rehearsal ($r = .69$, $p < .01$), and aggression control ($r = .64$, $p < .01$).

Conclusions. The findings highlight the interrelated nature of emotional regulation components and their variable contributions to athletic performance. These insights can guide the development of training programs incorporating emotional control strategies to enhance competitive outcomes for university athletes.

Keywords: emotional control, athletic performance, university athletes, competitive sports, emotional regulation.

Introduction

In competitive sports, success increasingly depends on having the capacity to identify and control one's own emotions as well as those of others. Emotional intelligence, which encompasses emotional awareness, regulation, and control, has been consistently linked to enhanced sports performance, especially in high-pressure environments (Akelaitis & Malinauskas, 2018). Athletes who can effectively manage their emotions are often better equipped to handle

the psychological and physical demands of competition, leading to improved performance outcomes. Researchers have become more aware of the complex impact that emotions play in sports performance during the last 20 years, demonstrating that emotional intelligence can be as important as physical and technical skills (Birwatkar, 2014). Emotions influence not only individual performance but also interpersonal dynamics within teams, where athletes must navigate their own emotional states alongside those of their teammates and opponents.

In today's high-performance sports environment, physical prowess alone is no longer sufficient for success. While physical conditioning, skill development, and

tactical awareness are critical, they must be supported by the capacity of an athlete to manage the emotional and psychological challenges of competition (Laborde et al., 2016; Korobeynikov et al., 2013). Emotional regulation allows athletes to maintain focus and composure, even when facing adversity, such as an unexpected defeat, an error in play, or the pressure of performing in front of a large audience. The ability to stay emotionally balanced under these conditions is vital to achieving consistent, high-level performance. Athletes with high emotional intelligence can also better manage interactions with coaches, referees, teammates, and opponents, making them more resilient and adaptable (Hodgson, 2018; Gatsis et al., 2021). This study aims to investigate the role of emotional intelligence in the performance and psychological well-being of athletes from diverse cultural contexts. Specifically, it focuses on comparing university-level athletes from Delhi University in India and Baghdad University in Iraq. By examining emotional awareness, regulation, and control among these groups, the research seeks to highlight the influence of cultural and social factors on emotional intelligence in sports.

Sport psychology research demonstrates that athletes who perform better on emotional intelligence tests typically have greater success, both in individual and team sports (Crombie et al., 2009). Emotional intelligence enables athletes to engage in positive psychological behaviors, such as goal-setting, self-motivation, and self-regulation, all of which are critical for long-term athletic success. For instance, emotional control helps athletes manage pre-competition anxiety, leading to lower stress levels and better overall performance (Lane & Wilson, 2011; Lu et al., 2010). Furthermore, emotional intelligence facilitates the application of psychological techniques, such as imagery, self-talk, relaxation, and reframing, which are essential tools for athletes facing the mental and physical pressures of competition (Lane et al., 2009; Crust & Azadi, 2010). These skills not only enhance performance but also contribute to the development of mental toughness, enabling athletes to overcome challenges and bounce back from setbacks more effectively. The study hypothesizes that athletes with higher levels of emotional intelligence will demonstrate superior performance, enhanced psychological resilience, and better interpersonal dynamics. Additionally, it is expected that cultural differences between Indian and Iraqi athletes will influence the ways emotional intelligence manifests in competitive sports settings.

Another important aspect of emotional intelligence in sports is its impact on team dynamics and interpersonal relationships. In team sports, athletes with high emotional intelligence can effectively navigate group interactions, using emotional awareness and empathy to foster cooperation and reduce conflicts (Singh et al., 2012; Rahman & Islam, 2021). These athletes are often better at reading the emotional states of their teammates and adjusting their own behavior accordingly, which can lead to better communication, stronger teamwork, and improved collective performance. Moreover, emotional intelligence can also enhance leadership qualities in athletes, as they are able to use their emotional awareness to inspire and motivate others, creating a positive team environment (Mayer, 2000). Athletes who demonstrate high emotional control are not only able to perform under pressure but also help their teammates manage stress, which is particularly important in high-stakes competitions.

The psychological and physiological benefits of emotional intelligence in sports are well-documented. For example, athletes with higher emotional intelligence tend to experience fewer physiological stress responses, such as elevated heart rates and muscle tension, which can negatively impact performance (Tinker, 2021). Emotional regulation helps athletes maintain optimal arousal levels, preventing over-excitement or under-arousal, both of which can hinder performance. Studies have shown that athletes with strong emotional control are more likely to enter and sustain «flow states,» where they experience heightened concentration and seamless execution of skills (Martinent et al., 2015). These athletes are better equipped to cope with the ups and downs of competition, staying focused on the task at hand rather than being distracted by external pressures or internal doubts.

Additionally, emotional intelligence is crucial in motivation and long-term success in sports. Athletes with high emotional intelligence are often more intrinsically motivated, driven by personal goals and a desire for self-improvement rather than external rewards (Kajbafnezhad et al., 2012). This self-motivation allows them to persevere through difficult training regimes and maintain their focus over the course of a season. Additionally, emotional intelligence enables athletes to set realistic, achievable goals and to stay committed to those goals, even in the face of obstacles. By managing their emotions, athletes can stay resilient and maintain a positive attitude, which is critical for long-term success in competitive sports (Lane et al., 2009).

In the context of athletes from different cultural backgrounds, such as those from the University of Delhi and the University of Baghdad, emotional control is particularly significant. Cultural differences can influence the way emotions are expressed and managed, both in everyday life and in competitive sports settings. Athletes from different cultures may have varying approaches to handling stress, competition, and teamwork, which makes emotional intelligence a valuable skill for navigating these differences (Lane et al., 2009). For university athletes from Delhi and Baghdad, the ability to regulate their emotions effectively is essential for performing at their best in diverse and competitive environments. Emotional intelligence allows them to adapt to the psychological and social demands of their respective sports, giving them a competitive edge on the field.

While this study provides valuable insights into the role of emotional intelligence in sports performance, it is not without limitations. First, the reliance on self-reported measures of emotional intelligence may introduce biases related to participants' self-perception. Second, cultural differences in expressing and interpreting emotions may affect the comparability of results between Indian and Iraqi athletes. Finally, the study's focus on university-level athletes may limit the generalizability of findings to professional or amateur sports populations.

Overall, the ability to control emotions is a crucial factor in determining athletic success, especially in high-pressure competitive environments. Whether in individual or team sports, emotional intelligence helps athletes manage stress, maintain focus, and perform consistently at their best. It also enhances their interpersonal skills, making them better teammates and leaders. In light of the growing recognition of emotional intelligence in sports, it is clear that developing emotional regulation skills can significantly impact on the performance of an athlete and overall health.

Materials and Methods

Study Participants

A total of 300 athletes, aged 18 to 30 years, participated in this study. The sample consisted of 150 athletes from the University of Baghdad (BU), Iraq and 150 athletes from the University of Delhi (DU), India, evenly divided between genders, with 75 male and 75 female athletes from each university. A purposive sampling technique, combined with a non-probability quota method, was employed to ensure equal representation from both institutions. Inclusion criteria required participants to provide complete and accurate responses, resulting in a final sample size of 300 athletes. This sample was designed to ensure comparability and represent diverse cultural and athletic backgrounds from Iraq and India.

Study Organization

To ensure accuracy and consistency, data collection was standardized across sites. Emotional control was assessed using the Emotional Control Questionnaire (ECQ), developed by Roger and Najarian (1989). This validated instrument evaluates emotional regulation through four subscales: Rehearsal, Emotional Inhibition, Aggression Control, and Benign Control, comprising 56 true/false items. The ECQ has demonstrated strong internal consistency, with reliability coefficients ranging from 0.77 to 0.86.

Participants completed the ECQ independently during testing sessions held in controlled environments at BU and DU. The purpose of the study was explained in detail before data collection, and informed consent was obtained from all participants. Trained researchers supervised the process to ensure procedural integrity. This methodological approach minimized potential biases and ensured that the emotional control data reflected the athletes' capacity to regulate emotions in a sports performance context.

Statistical Analysis

Data analysis was conducted using SPSS software to explore emotional control patterns among athletes. Descriptive statistics, including means and standard deviations, were calculated for all ECQ subscales—

Rehearsal, Emotional Inhibition, Aggression Control, and Benign Control—across the two universities.

A two-way ANOVA was performed to examine the main effects of university affiliation (BU vs. DU) and gender, as well as their interaction effects, on emotional control subscales. Post-hoc tests were conducted where significant differences were detected to further analyze group differences. Pearson's correlation coefficient was used to assess relationships among the ECQ subscales, with statistical significance set at $p < 0.05$. This robust analytical approach provided a comprehensive understanding of emotional control dimensions across cultural and gender-based contexts.

Results

Table 1 presents descriptive data on emotional regulation, broken down by gender, for sports majors from the Universities of Baghdad and Delhi, reported as mean $\pm$ standard deviation. The corresponding mean and standard deviation scores are displayed in Figure 1 and 2.

Descriptive statistics (mean $\pm$ SD) of emotional control among sports majors are presented for athletes from Baghdad University (BU) and Delhi University (DU), separated by gender and university affiliation. The table includes measurements for emotional control, rehearsal, emotional inhibition, aggression control, and benign control. For male athletes from BU ($n = 75$), the mean emotional control score was 33.94 ($SD = 6.67$), while female athletes from BU ($n = 75$) scored slightly higher at 34.88 ($SD = 4.91$). The overall score for BU athletes ($n = 150$) was 34.41 ($SD = 5.86$). Male athletes from DU ($n = 75$) had a mean score of 34.74 ($SD = 3.53$), and female athletes from DU ($n = 75$) had a mean score of 34.57 ($SD = 3.41$), with an overall DU score of 34.66 ($SD = 3.46$). When considering all male athletes ($n = 150$), the emotional control mean was 34.34 ($SD = 5.33$), and for all female athletes ($n = 150$), the mean was 34.72 ($SD = 4.22$). The overall emotional control score across all athletes ($n = 300$) was 34.53 ($SD = 4.80$). Rehearsal, emotional inhibition, aggression control, and benign control scores followed similar reporting formats across the different groups. This table highlights the comparative emotional control dynamics between male and female athletes from BU and DU, with overall balanced scores between genders and universities.

Table 1. Descriptive statistics (mean $\pm$ SD) of emotional control among sports majors

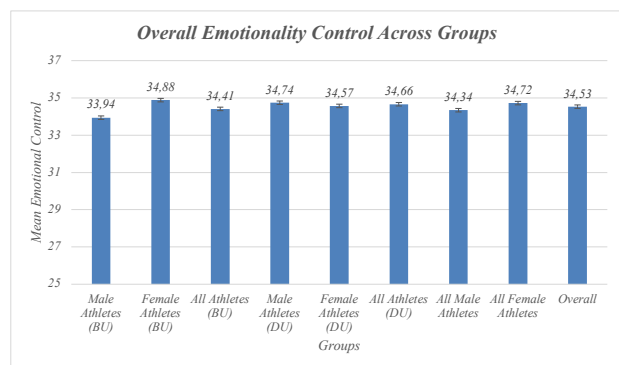
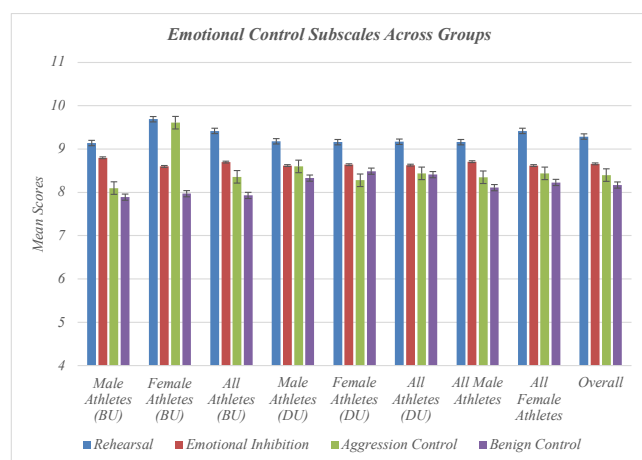
Subjects	n	Emotional Control	Rehearsal	Emotional Inhibition	Aggression Control	Benign Control
Male Athletes (BU)	75	33.94 $\pm$ 6.67	9.14 $\pm$ 2.35	8.80 $\pm$ 1.89	8.10 $\pm$ 2.41	7.89 $\pm$ 2.01
Female Athletes (BU)	75	34.88 $\pm$ 4.91	9.69 $\pm$ 2.03	8.60 $\pm$ 1.59	9.61 $\pm$ 2.00	7.97 $\pm$ 1.80
All Athletes (BU)	150	34.41 $\pm$ 5.86	9.42 $\pm$ 2.21	8.70 $\pm$ 1.74	8.36 $\pm$ 2.22	7.93 $\pm$ 1.90
Male Athletes (DU)	75	34.74 $\pm$ 3.53	9.18 $\pm$ 1.61	8.62 $\pm$ 1.62	8.60 $\pm$ 1.80	8.33 $\pm$ 1.65
Female Athletes (DU)	75	34.57 $\pm$ 3.41	9.16 $\pm$ 1.53	8.64 $\pm$ 1.38	8.28 $\pm$ 1.54	8.49 $\pm$ 1.54
All Athletes (DU)	150	34.66 $\pm$ 3.46	9.17 $\pm$ 1.57	8.63 $\pm$ 1.50	8.44 $\pm$ 1.68	8.41 $\pm$ 1.59
All Male Athletes	150	34.34 $\pm$ 5.33	9.16 $\pm$ 2.01	8.71 $\pm$ 1.76	8.35 $\pm$ 2.13	8.11 $\pm$ 1.84
All Female Athletes	150	34.72 $\pm$ 4.22	9.42 $\pm$ 1.81	8.62 $\pm$ 1.48	8.44 $\pm$ 1.79	8.23 $\pm$ 1.69
Overall	300	34.53 $\pm$ 4.80	9.29 $\pm$ 1.91	8.66 $\pm$ 1.62	8.40 $\pm$ 1.97	8.17 $\pm$ 1.77

Note: Values are expressed as means $\pm$ standard deviations. BU: Baghdad University; DU: Delhi University

Table 2. Summary of two-way ANOVA of emotional control among sports majors

Variables	Source of Variation	Sum of Squares	df	Mean Square	F-value	p-value
Emotional Control	Types of Players (A)	4.56	1	4.56	0.19	0.67
	Gender (B)	10.83	1	10.83	0.46	0.50
	(A × B)	22.96	1	22.96	0.98	0.32
Rehearsal	Types of Players (A)	4.56	1	4.56	1.24	0.26
	Gender (B)	5.07	1	5.07	1.38	0.24
	(A × B)	6.16	1	6.16	1.68	0.20
Emotional Inhibition	Types of Players (A)	0.33	1	0.33	0.12	0.73
	Gender (B)	0.65	1	0.65	0.24	0.63
	(A × B)	0.85	1	0.85	0.31	0.58
Aggression Control	Types of Players (A)	0.48	1	0.48	0.12	0.73
	Gender (B)	0.65	1	0.65	0.17	0.68
	(A × B)	12.81	1	12.81	3.30	0.07
Benign Control	Types of Players (A)	17.28	1	17.28	5.55	0.02
	Gender (B)	1.08	1	1.08	0.34	0.56
	(A × B)	0.12	1	0.12	0.03	0.86

Note. The table shows the results of a two-way ANOVA, including F-values and p-values for each variable

**Fig. 1.** Overall emotional control scores among male and female athletes from BU and DU**Fig. 2.** Comparison of emotional control subscales among sports majors

The summary of the two-way ANOVA for emotional control among sports majors is presented in Table 2. The analysis examined the main effects of the types of players (A) and gender (B), as well as their interaction (A × B), across five variables: emotional control, rehearsal, emotional inhibition, aggression control, and benign control.

For emotional control, neither the types of players ($F_{(1, 298)} = 0.19$, $p > 0.05$), gender ($F_{(1, 298)} = 0.46$, $p > 0.05$), nor their interaction ($F_{(1, 298)} = 0.98$, $p > 0.05$) showed statistically significant effects. Similarly, for rehearsal, no significant differences were found for the types of players ($F_{(1, 298)} = 1.24$, $p > 0.05$), gender ($F_{(1, 298)} = 1.38$, $p > 0.05$), or their interaction ($F_{(1, 298)} = 1.68$, $p > 0.05$). Emotional inhibition also revealed non-significant effects for both the types of players ($F_{(1, 298)} = 0.12$, $p > 0.05$), gender ($F_{(1, 298)} = 0.24$, $p > 0.05$), and their interaction ($F_{(1, 298)} = 0.31$, $p > 0.05$).

For aggression control, no significant effects were found for the types of players ($F_{(1, 298)} = 0.12$, $p > 0.05$), gender ($F_{(1, 298)} = 0.17$, $p > 0.05$), or the interaction ($F_{(1, 298)} = 3.30$, $p > 0.05$). However, a statistically significant effect was observed for benign control based on the types of players ($F_{(1, 298)} = 5.55$, $p = 0.02$), indicating a meaningful difference between groups. Specifically, athletes from Delhi University exhibited significantly higher scores in benign control compared to athletes from Baghdad University. Gender and the interaction effect for benign control were not significant ($F_{(1, 298)} = 0.34$, $p > 0.05$; $F_{(1, 298)} = 0.03$, $p > 0.05$, respectively).

This table suggests that types of players had a significant impact on benign control, while the other variables did not show significant differences.

Table 3 presents the correlation matrix of emotional regulation variables among athletes from the University of Delhi and University of Baghdad across all sports majors. The variables include Emotional Control, Rehearsal, Emotional Inhibition, Aggression Control, and Benign Control. Pearson correlation coefficients (r) were

Table 3. Correlation matrix of emotional regulation variables among athletes

Variables	Emotional Control	Rehearsal	Emotional Inhibition	Aggression Control	Benign Control
Emotional Control	1				
Rehearsal	.69**	1			
Emotional Inhibition	.61**	.26**	1		
Aggression Control	.64**	.20**	.25**	1	
Benign Control	.69**	.31**	.17**	.27**	1

Note: **. Correlation is significant at the 0.01 level (2-tailed)

computed to examine the relationships between these variables. Significant positive correlations were observed between most variables, with Emotional Control showing strong correlations with Benign Control ($r = .69, p < .01$), Rehearsal ($r = .69, p < .01$), and Aggression Control ($r = .64, p < .01$). Rehearsal also correlated positively with Emotional Inhibition ($r = .26, p < .01$) and Benign Control ($r = .31, p < .01$), though these correlations were weaker compared to Emotional Control. Additionally, there were moderate correlations between Emotional Inhibition and Aggression Control ($r = .25, p < .01$) and between Emotional Inhibition and Benign Control ($r = .17, p < .01$). These findings suggest that while the variables are interrelated, the strength of these relationships varies, providing insight into how different facets of emotional regulation interact in athletes. $p < .01$ indicates significance for all reported correlations.

Discussion

The analysis of emotional control among athletes from Baghdad University (BU) and Delhi University (DU) provides valuable insights into how athletes regulate their emotions across different dimensions; these include areas such as rehearsal, emotional inhibition, aggression control, and benign control. A comparative look at the descriptive statistics (Table 1) reveals subtle differences between male and female athletes as well as between universities. Overall, the emotional control scores across all groups were fairly consistent, with BU athletes having a slightly lower mean emotional control score (34.41 ± 5.86) compared to DU athletes (34.66 ± 3.46). This suggests that both universities maintain a similar emphasis on emotional regulation in their athletes, although the lower standard deviation in DU athletes indicates less variability in emotional control scores within this group. These findings align with previous studies that have identified emotional regulation as a critical component in athletic performance, with little difference between institutions or genders (Robazza et al., 2004; Robazza & McCarthy, 2018; Beatty & Janelle, 2020).

Male and female athletes demonstrated relatively balanced emotional control, although female athletes from BU had a slightly higher emotional control score (34.88 ± 4.91) compared to males (33.94 ± 6.67). Similarly, female athletes from DU scored marginally lower than males in rehearsal but maintained similar scores across the other emotional regulation dimensions. The slightly higher scores for women in BU in categories like aggression control (9.61 ± 2.00 vs. 8.10 ± 2.41 for men) could point to better

developed mechanisms for managing aggressive impulses, which aligns with research suggesting that female athletes often employ more nuanced emotional regulation strategies (Kucharski et al., 2018; Wilson et al., 2019).

The two-way ANOVA (Table 2) further examines the role of gender and the type of players in determining emotional control and its related dimensions. Interestingly, there were no significant main effects of either player type ($F_{(1, 298)} = 0.19, p > 0.05$) or gender ($F_{(1, 298)} = 0.46, p > 0.05$) on emotional control, rehearsal, or emotional inhibition. These non-significant results suggest that the type of player—whether from BU or DU—or their gender does not substantially impact their ability to regulate emotions, aligning with findings from previous studies in sports psychology. The interaction effect between gender and player type also showed no significant effects across these variables, indicating that emotional regulation capabilities remain relatively stable regardless of the intersection between these two factors (Mercader-Rubio et al., 2022).

However, an interesting exception is found in the dimension of benign control, where a significant effect of player type was observed ($F_{(1, 298)} = 5.55, p = 0.02$). Athletes from different universities exhibited meaningful differences in their ability to exercise benign control, which pertains to the regulation of non-threatening and calming behaviors. Notably, athletes from Delhi University demonstrated significantly higher benign control scores compared to their counterparts from Baghdad University. This suggests that DU players may possess better-developed mechanisms for managing calming and non-aggressive emotional responses, which could be attributed to differences in coaching strategies, training environments, or cultural influences. These findings align with studies suggesting that benign control may be shaped by external factors, such as team dynamics, coaching approaches, or societal norms (Shoukry & Cox, 2018).

In terms of correlations among the emotional regulation variables (Table 3), emotional control exhibited strong positive correlations with benign control ($r = .69, p < .01$), rehearsal ($r = .69, p < .01$), and aggression control ($r = .64, p < .01$). These findings imply that athletes who are skilled at controlling their emotions are also adept at rehearsing emotional responses and managing aggressive tendencies. This relationship aligns with models of emotional regulation that highlight the interconnectedness of these dimensions in athletic contexts (Martin et al., 2016).

Interestingly, rehearsal had weaker correlations with emotional inhibition ($r = .26, p < .01$) and benign control

($r = .31$, $p < .01$), suggesting that while rehearsal plays an important role in emotional regulation; it is not as strongly associated with the inhibition or calming aspects of emotional regulation. This could imply that rehearsal primarily helps athletes prepare for emotional responses but does not necessarily translate into better control over emotional inhibition or benign responses in real-time situations (Ignacio et al., 2017). Similarly, moderate correlations were found between emotional inhibition and both aggression control ($r = .25$, $p < .01$) and benign control ($r = .17$, $p < .01$), indicating a degree of overlap in these regulation processes, though less pronounced compared to emotional control (Pawliczek et al., 2013; Hsieh & Chen, 2017).

The significant correlations across most variables indicate that emotional regulation is a multi-faceted construct where improvements in one area often support enhancements in others. This finding supports previous research in sports psychology, which posits that the ability to regulate emotions across different dimensions can lead to more adaptive emotional responses and improved athletic performance (Tang et al., 2022). Moreover, the strong correlation between emotional control and benign control, in particular, highlights the importance of managing both aggressive and calming responses in high-pressure sports environments (Ciarrochi & Scott, 2006).

While these findings offer valuable insights, they also open avenues for future research. Future research could explore longitudinal trends in emotional regulation to determine its development over time in athletes. Additionally, studies incorporating physiological metrics, such as heart rate variability, could provide a holistic view of emotional regulation. Expanding this research to include athletes from diverse cultural or professional settings would enhance the generalizability of these findings.

These avenues for further exploration underline the multifaceted nature of emotional regulation and its pivotal role in athletic performance, offering a foundation for deeper insights and practical applications.

Conclusions

Although the majority of factors did not significantly differ across groups, the study does highlight noteworthy tendencies in emotional regulation among athletes of diverse genders and university backgrounds. The noteworthy correlation in benign control among distinct player types indicates the impact of contextual elements like coaching and team culture. Furthermore, the intricate interactions between many facets of emotional control in athletes are highlighted by the intercorrelations among emotional regulation factors. Future studies should delve deeper into these interactions, especially as they relate to the ways that benign control and other regulating tactics are shaped by outside factors.

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Conflicts of Interest

The authors declared no conflict of interest..

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Аналіз емоційного контролю університетських спортсменів: Крос-культурна та гендерна перспектива

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

Реферат. Стаття: 8 с., 3 табл., 3 рис., 31 джерело.

Історія питання. Емоційний контроль відіграє вирішальну роль у досягненні спортивної результативності і залежить від таких факторів, як стать і культурний контекст. Розуміння взаємозв'язку між емоційною регуляцією та спортивними успіхами може стати цінним підґрунтям задля оптимізації стратегій результативності.

Мета дослідження. Метою цього дослідження було вивчити роль емоційного контролю у досягненні спортивної результативності серед студентів-спортсменів з Багдада (Ірак) та Делі (Індія), приділяючи особливу увагу вивченню відмінностей згідно з гендерною та університетською приналежністю. У дослідженні також розглядаються взаємозв'язки між субшкалами емоційного контролю та загальною результативністю.

Матеріали та методи. У дослідженні взяли участь 300 спортсменів віком від 18 до 30 років, яких порівнювало розподілено між Багдадським університетом (БУ), Ірак, і Делійським університетом (ДУ), Індія, за принципом збалансованого гендерного співвідношення (75 спортсменів-чоловіків і 75 спортсменів-жінок від кожного університету). Оцінка емоційного контролю проводилася за допомогою опитувальника емоційного контролю ("Emotional Control Questionnaire", ECQ), який містить субшкали для повторюваного типу мислення, емоційної інгібіції, контролю агресії та сприятливого контролю. Для аналізу даних було застосовано описову статистику, двофакторний дисперсійний аналіз (ANOVA) та кореляції Пірсона із використанням програмного забезпечення SPSS.

Результати. Показники емоційного контролю були порівнянними як для університетів, так і для обох статевих груп, причому спортсмени БУ набрали дещо менше балів ($M = 34,41$, $SD = 5,86$), ніж спортсмени ДУ ($M = 34,66$, $SD = 3,46$). Двофакторний дисперсійний аналіз не виявив значущих відмінностей у показниках загального емоційного контролю або його субшкал залежно від статі, університетської приналежності або їхньої взаємодії, за винятком сприятливого контролю, де спортсмени ДУ отримали значно вищі результати ($F_{(1, 298)} = 5,55$, $p = 0,02$). Встановлено міцні позитивні кореляції між загальним емоційним контролем і субшкалами сприятливого контролю ($r = .69$, $p < .01$), повторюваним типом мислення ($r = .69$, $p < .01$) та контролем агресії ($r = .64$, $p < .01$).

Висновки. Отримані дані підкреслюють взаємопов'язаний характер компонентів емоційної регуляції та їхній варіативний внесок у досягнення спортивної результативності. Зазначені висновки можуть слугувати орієнтиром для розроблення тренувальних програм, що включатимуть стратегії емоційного контролю щодо підвищення змагальних результатів університетських спортсменів.

Ключові слова: емоційний контроль, спортивна результативність, університетські спортсмени, змагальні види спорту, емоційна регуляція.

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Enhancing Physical Fitness in Male Basketball Players through Yogic Asanas: A Randomized Controlled Trial

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Abstract

Background. The increasing popularity of yoga as a complementary training method has prompted interest in its effects on physical fitness among male basketball players.

Objectives. This study aimed to assess the impact of yogic asanas on physical fitness variables in male basketball players. The primary objective of this research was to determine the effectiveness of yoga asana practice on cardiorespiratory endurance (CVE), muscular strength (MS), muscular endurance (ME), and flexibility (FLE) in male basketball players.

Materials and methods. A total of 41 male basketball players were involved in the study and randomly assigned to two groups: the Yoga Asanas Group (YAG) comprising 21 players (age: 18.44 ± 0.98 years, height: 171 ± 4.45 cm, weight: 87.94 ± 4.26 kg) and the Control Group (CON) with 20 players (age: 18.93 ± 1.38 years, height: 174 ± 6.21 cm, weight: 91.31 ± 7.00 kg). Physical fitness parameters were assessed before and after the intervention.

Results. The results demonstrated a statistically significant improvement in physical fitness variables among players in the YAG, with p-values less than 0.05 for CVE ($p < 0.001$), MS ($p < 0.001$), ME ($p < 0.001$), and FLE ($p < 0.001$) following yoga asana practice. In contrast, the CON group exhibited no substantial changes ($p > 0.05$).

Conclusions. The findings of this experimental study suggest that incorporating yogic asanas into training regimens significantly enhances physical fitness parameters in male basketball players, highlighting the potential benefits of yoga as an effective training modality.

Keywords: basketball players, yogic asana, muscular strength, muscular endurance, flexibility.

Introduction

High level of physical fitness is a foundation of success in sports especially in fast-paced and high-intensity games like basketball (Farley et al., 2020; Mancha-Triguero et al., 2019). Athletes need a well-versed set of skills, including strength, endurance, agility, and flexibility to stay competitive (Puente et al., 2017). Most of the training programs emphasize drills, strength-building routines and cardio workouts to build

these essential qualities. In recent times, there has been a growing interest in integrating the new elements to these traditional methods to enhance overall athletic performance. One practice that is gaining traction is yoga, which promises benefits that extend beyond the purely physical to also support mental well-being (Vogler et al., 2023; Woodyard, 2011).

Yoga has been around for thousands of years, originating in ancient India as a practice that combined physical postures, breathing exercises, and meditation. Over time, it has evolved into a recognized training tool that can improve flexibility, core strength, balance, and mental focus. These attributes are crucial for athletes, especially for basketball players who need to make sharp, quick movements and maintain balance

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under pressure (Shao et al., 2023). Yoga has the potential to enhance an athlete's body control with accumulative their adaptability and agility on the court (Alleva et al., 2020; Kaltenborn & Ryba, 2006). In addition to its physical advantages, yoga provides substantial mental and emotional reinforcement (Ross et al., 2013). The pressures associated with competitive sports can be formidable, requiring athletes to execute instantaneous decisions and sustain concentration in critical scenarios. The yoga have demonstrated efficacy in alleviating stress, enhancing concentration, and fostering resilience providing athletes with a psychological advantage that enables them to maintain composure during pivotal moments in competition (Kanauija et al., 2023).

The investigation into yoga as an adjunctive practice within the realm of sports training has progressively garnered attention over time. Initial research on the advantages of yoga primarily concentrated on its capacity to improve flexibility and alleviate stress. The studies established a basis for understanding the extensive potential of yoga beyond conventional health and wellness domains, demonstrating that consistent practice could yield considerable physical and psychological advantages (Kishan, 2020; Nayak & Verma, 2023; Woodyard, 2011).

Recent scholarly works have increasingly explored the application of yoga within the context of athletic environments. Studies have shown that engaging in yoga can enhance multiple dimensions of physical fitness, such as balance, core stability, and flexibility attributes essential for numerous sports, including basketball (Bucea-Manea-Țoniș et al., 2023; Kaltenborn & Ryba, 2006; Woodyard, 2011). For example, studies have shown that certain asanas can enhance the range of motion and reduce the risk of injury by improving muscle elasticity and joint health (Halappa, 2023; Niemaszzyk & Truszczyńska-Baszak, 2023).

When it comes to cardiovascular endurance (CVE), muscular strength (MS), and muscular endurance (ME), the findings are mixed but promising. Some studies have indicated that incorporating yoga into a training regimen can lead to modest improvements in cardiovascular health and muscular performance (Lau et al., 2015). For example, research conducted on athletes from various disciplines found that integrating yoga sessions into their regular training helped enhance their recovery and overall fitness levels (Bucea-Manea-Țoniș et al., 2023; Halappa, 2023). However, these studies often focused on general fitness populations or athletes in non-competitive contexts.

While the existing literature supports the idea that yoga offers numerous benefits, the evidence is less robust when it comes to high-performance sports, especially for basketball players. The few studies that have explored yoga's role in competitive sports suggest that it can improve agility and reaction times, but these findings are typically part of broader investigations without a specific focus on key fitness parameters like CVE, MS, ME, and FLE in basketball athletes. The research gap is evident: while yoga's role in improving flexibility and mental health has been documented, comprehensive studies examining its impact on core physical fitness metrics for competitive basketball remain limited (Bucea-Manea-Țoniș et al., 2023; Vaidya et al., 2021; Woodyard, 2011).

This gap in the literature highlights the need for more targeted research that evaluates the practical application of

yoga within structured training programs for athletes. Thus, this study aims to fill that gap by examining the effects of a 12-week yoga asana program on key fitness markers in male basketball players. By using a randomized controlled trial (RCT), we can ensure a fair comparison between players who incorporate yoga into their training (Yoga Asanas Group, YAG) and those who stick to their usual training routines (Control Group, CON). We'll measure their physical fitness before and after the intervention to see if the yoga practice leads to improvements in CVE, MS, ME, and FLE.

Materials and Methods

Study Design

This study was conducted to determine if practicing yogic asanas (specific yoga poses) can improve physical fitness in male basketball players. To do this, we used a method called a randomized controlled trial. In this design, participants were randomly assigned to either a Yoga Asanas Group (who practiced yoga) or a Control Group (who did not practice yoga). This random assignment helps ensure that each group is as similar as possible, except for the yoga intervention. Measurements were taken twice: once before the 12-week yoga program started and again at the end of 12 weeks. This way, we could clearly observe any changes due to the yoga program.

Subjects

At the enrollment stage (Initial stage), male basketball players aged 18 to 24 years from the Indian Institute of Information Technology, Sri City, Chittoor were employed for the participation. Each player and, where needed, their guardians, provided consent to participate after we explained the study procedures to them. We used a careful screening process to select eligible players. This screening involved making sure participants met certain criteria for age, health, and basketball experience, and that they did not have any injuries or conditions that could interfere with yoga practice or the study results.

Sample Size

To decide how many participants we needed, we referred to a previous similar study by (Mohr et al., 2014). According to this study, 41 players would be sufficient to give us reliable results. Thus, we recruited 41 players and randomly assigned them into two groups: the Yoga Asanas Group (YAG) with 21 players and the Control Group (CON) with 20 players. This sample size allows us to make solid conclusions about how yogic asanas might affect physical fitness.

Randomization

In our initial screening, we found 64 players who met the eligibility criteria. However, due to factors like scheduling conflicts or potential dropouts, only 41 were ultimately able to participate in the study depicted in figure 1. Each player was given a clear explanation of the study's aims, methods, and the possibility of dropouts. Then, using a random allocation method, we assigned each player to either the Yoga Asanas Group (YAG) or the Control Group (CON), ensuring that both groups started out with similar characteristics.

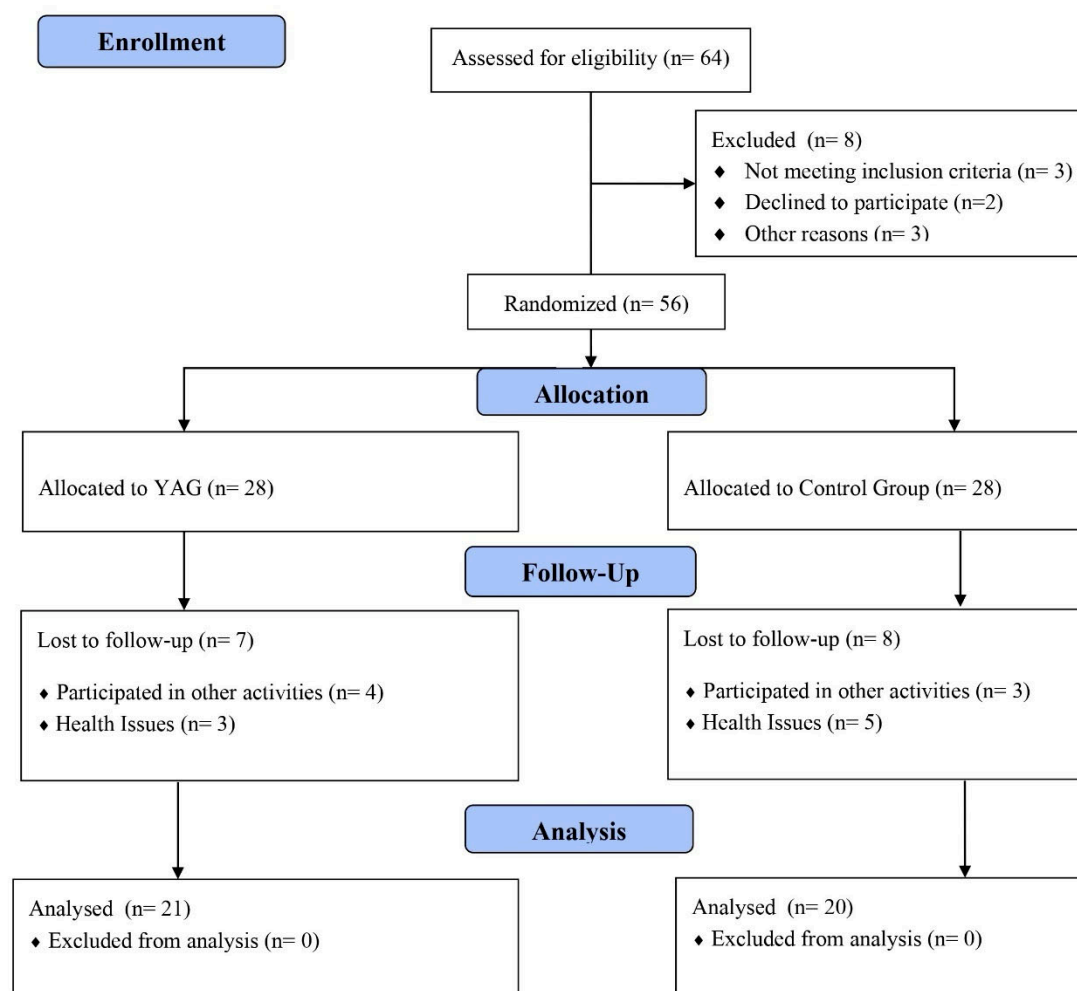


Fig. 1. Subject recruitment flow diagram

Blinding/Masking

We used a technique called “blinding” to help prevent any bias in the results. In this case, the researchers who measured the players’ fitness at the end of the study did not know which group each player belonged to. This helped ensure that the results were objective and unaffected by any preconceptions. However, players knew which group they were in, as the yoga practice could not be hidden from them.

Yogic Asanas Intervention

To ensure that all participants understood the purpose and procedures of the study, familiarization sessions were held as part of theory classes. During these sessions, each participant in YAG received a thorough introduction to the study design, objectives, and the specific yoga asanas they would be practicing. These sessions aimed to make participants comfortable with the techniques and terminology involved in yogic practices and ensure their readiness for the physical training sessions. Attendance was strictly recorded for all theory and practice sessions throughout the 12-week study period to monitor participant engagement and ensure consistency in participation. The YAG took part in a structured yoga program led by a certified yoga instructor

or a qualified BNYS (Bachelor of Naturopathy and Yogic Sciences) doctor. This program was designed specifically to improve fitness aspects like strength, flexibility, balance, and endurance. Each session lasted 60 minutes and was held three times a week over the 12-week period. Each yoga session included Warm-Up: Gentle stretches and movements to prepare the body for exercise. Yoga Asanas (Postures): Various yoga poses that focused on enhancing physical fitness. These poses were selected based on their potential benefits for athletes, such as improving flexibility, core strength, and balance. Relaxation Techniques: At the end of each session, players practiced relaxation techniques to promote recovery and mental calmness. During this time, the Control Group (CON) did not participate in the yoga program but continued with their regular basketball training routines. This allowed us to compare any changes in fitness between the players who practiced yoga and those who didn’t.

Outcome Measure

Anthropometry

Participants’ body weight was measured on an electronic scale (Seca, Hamburg, Germany) with a precision

Table 1. Exercise protocols for yoga asana group weekly session (n = 21)

Sl. No	Name of the Yoga Practices	Duration	Weeks
1.	Loosening Exercises	15 minutes	
	Jumping Jacks		
	High Knees		
	Butt Kicks		
	Arm Cercles		
	Leg Swing		
	Legs with a twist		
	Torso Rotation		
	Side shuffles		
	Inchworm		
2.	Hip circles	12 rounds / 15 minutes	1-4
	Suryanamasker		
	Asana		
	Tadasana (Mountain pose)		
	Vrikshasana (Tree pose)		
3.	Utkatasana (Chair Pose)	20 counts / 8 minutes	
	Trikonasana (Triangle pose),	2 minutes	
	Virabhadrasana	2 minutes	
	Malasana	1 minutes	
	Bitilasana (Cat cow Pose)	2 minutes	
	Kopotasana (Pigeon Pose)	3 minutes	
	Bhujangasana (Cobra Pose)	2 minutes	
	Savasana	6 minutes	
	Total	60 Minutes	
Sl. No	Name of the Yoga Practices	Duration	Weeks
1.	Loosening Exercises	12 minutes	
	Jumping Jacks		
	High Knees		
	Butt Kicks		
	Arm Cercles		
	Leg Swing		
	Legs with a twist		
	Torso Rotation		
	Side shuffles		
	Inchworm		
2.	Hip circles	12 rounds / 15 minutes	
	Suryanamasker		
	Asana		
	Tadasana (Mountain pose)		
	Vrikshasana (Tree pose)		
3.	Utkatasana (Chair Pose)	20 counts / 8 minutes	5-8
	Trikonasana (Triangle pose)	2 minutes	
	Parivrttra Trikonasana (Twist triangle pose)	2 minutes	
	Virabhadrasana (Warrior II)	2 minutes	
	Vajrasana	1 minutes	
	Malasana	1 minutes	
	Bitilasana (Cat cow Pose)	2 minutes	
	Kopotasana (Pigeon Pose)	2 minutes	
	Parvatasana (Mountain Pose)	1 minutes	
	Adho Mukha Savasana (Downward Facing Dog)	2 minutes	
4.	Bhujangasana (Cobra Pose)	1 minutes	
	Savasana	2 minutes	
	Meditation	3 minutes	
	Mindfulness meditation		
	Total	60 Minutes	

Table 1 (continued)

Sl. No	Name of the Yoga Practices	Duration	Weeks	
1.	Loosening Exercises	15 minutes		
	Jumping Jacks			
	High Knees			
	Butt Kicks			
	Arm Cercles			
	Leg Swing			
	Legs with a twist			
	Torso Rotation			
	Side shuffles			
	Inchworm			
	Hip circles			
	Knee Hugs			
	Ankle Circles			
	Dynamic Squats			
	Forward Lunges			
Neck Rolls				
2.	Suryanamasker	12 rounds / 12 minutes	9-12	
3.	Asana	30 minutes		
	Tadasana (Mountain pose)	2 minutes		
	Vrikshasana (Tree pose)	2 minutes		
	Utkatasana (Chair Pose)	12 counts / 8 minutes		
	Ardha Chandrasana	2 minutes		
	Parivrttra Trikonasana (Twist triangle pose)	2 minutes		
	Virabhadrasana (Warrior II)	2 minutes		
	Matsyendrasana (Fish Pose)	1 minutes		
	Kopotasana (Pigeon Pose)	1 minutes		
	Parvatasana (Mountain Pose)	1 minutes		
	Adho Mukha Savasana (Downward Facing Dog)	1 minutes		
	Setu bandhasana (Bridge Pose)	1 minutes		
	Bhujangasana (Cobra Pose)	1 minutes		
	Supta Padangusthasana	2 minutes		
	Viparitakarani (Legs up the well)	2 minutes		
	Savasana	2 minutes		
	4.	Meditation		3 minutes
		Mindfulness meditation		
Total				
		60 Minutes		

of 0.01 kg, while they were barefoot and wearing minimal clothing. Height was recorded to the nearest 0.1 cm using a stadiometer (Seca, Hamburg, Germany) following standardized measurement protocols (Govindasamy et al., 2024).

Cardiovascular Endurance (Cooper's 12-Minute Run)

Participants performed a 12-minute endurance run on an outdoor track, aiming to complete as many laps as possible within the time limit. They were instructed to pace themselves throughout the test. To support pacing, the administrator announced elapsed time intervals at 3, 6, and 9 minutes and provided verbal encouragement. At the end of the 12 minutes, participants were instructed to stop, and the administrator measured any incomplete final lap distance using a measuring wheel. This partial lap distance was added to the total completed laps to determine the final distance

covered. The total distance run was then used to estimate VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$) using Cooper's equation: $VO_{2max} (ml \cdot kg^{-1} \cdot min^{-1}) = (22.351 \times \text{distance in km}) - 11.288$ (Suresh et al., 2022).

Muscular Strength

The players begin lying on their back on a mat, with hands positioned beneath the shoulders, fingers extended, and legs straight, slightly apart. From this starting position, the student pushes against the mat until their arms are fully extended, keeping both legs and back straight. They then lower their body until their elbows form a 90-degree angle, with forearms parallel to the floor. Athletes were instructed to perform as many 90-degree push-ups as possible in time with a designated rhythm marked by cues of "down" and "up". The test was stopped if a student committed two faults, such as knees touching the ground, instability in the back,

incomplete arm extension, or failure to reach a 90-degree elbow angle. The final score was the total number of correctly executed push-ups (Govindasamy et al., 2023).

Muscular Endurance (Sit-Up Test)

Muscular endurance was assessed using a sit-up test (BS-SU, InBody, Seoul, Republic of Korea). Prior to the test, participants were instructed to lie supine on a mat, ensuring that their heads and upper backs remained in contact with the surface. Their knees were positioned at a 45° angle with a fist-sized gap between them. Throughout the test (while performing sit-ups), participants were required to keep their hands positioned behind their heads, maintaining this placement while executing sit-ups. They performed sit-ups continuously for a 60-second period, ensuring proper form and adherence to the specified technique. Each sit-up required both elbows to touch the knees before returning to the starting position. The endurance score was based on the total number of sit-ups completed within 30-second intervals. Participants were allowed to practice two to three times with assistance to familiarize themselves with the movement, and repetitions were counted aloud during the assessment to maintain consistency (Suresh et al., 2022).

Flexibility

The sit and reach test was performed according to precise instructions to assess lower body flexibility. While seated, participants extended forward as far as possible with one knee held straight. A sit and reach box was used to measure the reach distance of the hands in centimetres, providing an assessment of flexibility in the lower body (Govindasamy et al., 2023).

Table 2. Demographic parameters of the participants (n = 41)

Variables	Control Group	Yoga Asana Group	p value
Age	18.93 ± 1.38	18.44 ± 0.98	0.218*
Height	174.00 ± 6.21	171.00 ± 4.45	0.198*
Weight	91.31 ± 7.00	87.94 ± 4.26	0.109*

Notes: *Independent t-test result $p > 0.05$

Statistical Analysis

Data were expressed as mean values with standard deviations (SD) for each physical fitness parameter. The

normality of the data distribution was assessed using the Kolmogorov-Smirnov test. A p-value greater than 0.05 indicated a normal Gaussian distribution of the data. To evaluate the differences in physical fitness parameters between the two groups (yoga asana and non-yoga asana), paired t-tests were conducted for within-group comparisons. Additionally, between-group differences were analyzed using independent t-tests. Effect sizes were calculated using Cohen's d to determine the magnitude of differences observed. The mean differences between pre- and post-intervention scores were also calculated, providing insights into the extent of improvement attributable to the yoga asana intervention. Statistical significance was set at $p < 0.05$ for all analyses. Confidence intervals (CIs) were computed for mean changes to assess the precision of the estimates.

Results

Table 2 presents the anthropometric parameters of male basketball players divided into two groups: those practicing yoga asanas and those not practicing yoga asanas. At baseline, there were no significant differences in age, height, and other parameters between the two groups. A total of 64 individuals were screened for participation in the study, and out of these, 56 met the specified inclusion and exclusion criteria and were subsequently enrolled. During the study, seven participants from the yoga asana group and eight from the non-yoga asana group withdrew for various reasons, which are detailed in Figure 1. It is important to note that no adverse events were reported among participants who completed the study.

Table 3 illustrates a statistically significant improvement in various physical fitness variables among the basketball players in the yoga asana group, with p-values less than 0.05 for cardiorespiratory endurance (CVE: $p < 0.001$), muscular strength (MS: $p < 0.001$), muscular endurance (ME: $p < 0.001$), and flexibility (FLE: $p < 0.001$) following the yoga asana practice. Conversely, the basketball players in the non-yoga asana group did not exhibit any significant changes ($p > 0.05$) in these fitness parameters (Figure 2).

The yoga asana intervention demonstrated a substantial positive effect on physical fitness, with effect sizes indicating improvements: CVE (1.18), MS (0.92), ME (1.26), and FLE (2.51) (Figure 2). Furthermore, the mean change in physical fitness measures was notable: CVE improved by 2.12 (with a confidence interval of 1.74 to 0.61), MS by 0.36 (1.43 to 0.40), ME by 1.59 (1.83 to 0.67), and FLE by 1.82 (3.38 to 1.61).

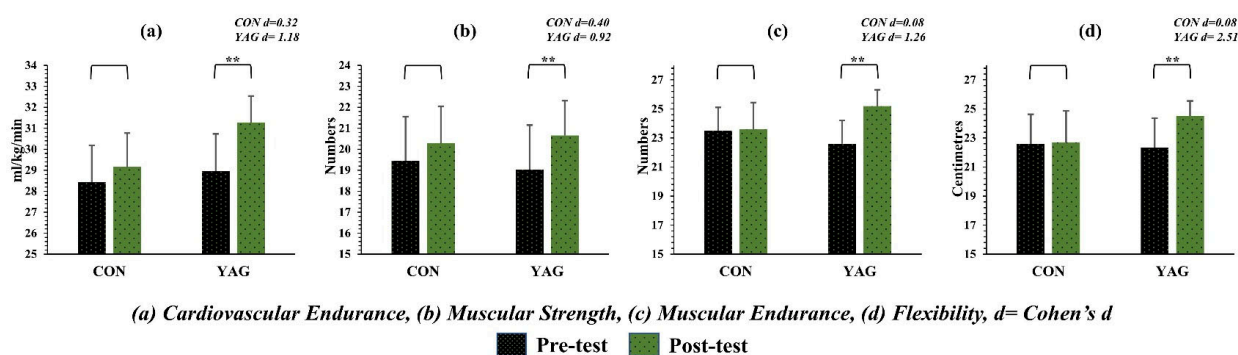


Fig. 2. The bar charts of physical fitness parameters before and after the intervention

Table 3. Comparison of Physical Fitness Parameters Between Basketball Players with Yoga Asanas and Without Yoga Asanas (n = 41)

Physical Fitness Parameters	CON (n=20)		p / % change	Cohen's d	YAG (n=21)		p / % change	Cohen's d	Between group difference (CI)
	Pre (M ± SD)	Post (M ± SD)			Pre (M ± SD)	Post (M ± SD)			
CVE ml·kg ⁻¹ ·min ⁻¹	28.42 ± 1.77	29.16 ± 1.61	0.16 / (2.60)	0.32	28.96 ± 2.03	31.28 ± 1.26	< .001 / (8.01)	1.18	2.12 (1.74-0.61)
MS Numbers	19.45 ± 2.11	20.30 ± 1.75	0.08 / (4.37)	0.40	19.04 ± 1.39	20.66 ± 1.65	< .001 / (8.50)	0.92	0.36 (1.43-0.40)
ME Numbers	23.50 ± 1.60	23.60 ± 1.84	0.72 / (0.42)	0.08	22.61 ± 2.17	25.19 ± 1.12	< .001 / (11.41)	1.26	1.59 (1.83-0.67)
FLE Centimetres	22.60 ± 2.03	22.70 ± 2.17	0.71 / (0.44)	0.08	22.33 ± 1.52	24.52 ± 1.03	< .001 / (9.80)	2.51	1.82 (3.38-1.61)

Notes: CVE; Cardiovascular endurance, MS; Muscular Strength, ME; Muscular Endurance, FLE; Flexibility, CON; Control group, YAG; Yoga asana group

Discussion

This study's results strongly suggest that a 12-week yogic asanas intervention can statistically significantly increase physical fitness parameters in male basketball players. There were dramatic improvements in these measures: cardiorespiratory endurance (CVE), muscular strength (MS), muscular endurance (ME), and flexibility (FLE) in the yoga group, but no significant changes in the control group. Furthermore, this finding demonstrates that yoga can significantly complement traditional athletic preparation, particularly for basketball.

The 8.01% change in CVE for the yoga group suggests that yoga practices, including breath control and prolonged isometric holds, may substantially affect an athlete's oxygen uptake and respiratory efficiency. Efficient CVE is particularly important in basketball, where players constantly perform at high-intensity efforts spaced by short recovery periods (Delextrat et al., 2018; Flórez Gil et al., 2024; Mihajlovic et al., 2023). Adding Surya Namaskar (Sun Salutation) and asanas that require rhythmic breathing, such as Utkatasana (Chair Pose), may help deliver more oxygen and stabilize cardiovascular stability, enabling athletes to perform consistently over long periods of demanding activity (Deshmukh et al., 2024; Luan et al., 2019). This finding provides evidence of yoga's benefits in enhancing aerobic conditioning as an alternative or additional method to traditional high-impact cardiovascular training with associated injury risk (Beck et al., 2017; Campbell et al., 2019; Ramos-Jiménez et al., 2015). Substituting yoga for endurance conditioning can help coaches and athletic trainers utilize a gentler, still effective way to build cardiovascular fitness in the joints and soft tissues.

A noteworthy finding is the 8.50 % improvement in MS observed in the yoga group in which the yoga intervention consisted of no external weights or traditional resistance exercises. These are asanas requiring prolonged engagement and isometric contraction: Virabhadrasana (Warrior Pose) and Tadasana (Mountain Pose), in which significant gains are had in MS. These poses serve as the foundation for developing multiple muscle groups simultaneously, with a particular emphasis on enhancing the endurance of lower extremity muscles and stabilizing muscles, which are areas

where basketball players depend on explosive power for jumping, sprinting and quick direction change (Anversha & Ramalingam, 2023; Luo et al., 2023). This increase in muscular strength from yoga, observed without weight or other equipment loading, suggests that yoga may be a functional and affordable intervention, particularly in environments where such strength training resources are inaccessible. Nevertheless, it should be known that although strength gain was significant, yoga may help strength endurance and muscle tone rather than maximal strength (Hosseini et al., 2018; Sarbaz et al., 2020). Also, future studies would potentially look into ways other styles of yoga, specifically ones that have dynamic transitions and longer holds, influence strength development regarding classic resistant training.

This onefold increase in ME in the yoga group demonstrates the effectiveness of the intervention in promoting continued muscular activation and endurance, most notably in core and lower body muscles (11.41 %). Trikonasana (Triangle Pose) and Vrksasana (Tree Pose), asanas which require balance and need continuous muscle activation (including through muscle contraction), build muscle endurance in muscles needed to stabilize for continuous high-intensity movement involved in basketball (Luo et al., 2023; Rhyu et al., 2018). Lower body endurance for sprinting and jumping and core stability for dynamic movement and impact absorption are the two critical areas of athleticism needed in basketball athletes (Cao et al., 2024; Luo et al., 2023), so yoga will help reach these areas. According to the increase in ME, yoga's approach to continuous, steady muscle engagement may create endurance differently than a regimented, repetition-based protocol. These benefits are apparent, but further investigation is warranted to see if yoga is equally effective at building stamina in fast-twitch muscle fibres as plyometrics or interval training, which are standard ways to build stamina within fast-twitch muscle fibres.

A particularly substantial increase in FLE, at 9.80 %, is a significant boost for those in the athletic field; increased mobility can allow for an increased range of motion, reduce the risk of injury, and increase the efficiency of movement. Bhujangasana (Cobra Pose) and Savasana (Corpse Pose) asanas are great for sports like basketball that require dynamic stretching and muscle lengthening (especially for

movements such as squatting, jumping and going in any direction). Athletes get better depth in their joint movements and less resistance during dynamic actions, leading to better agility, less strain, and less risk of joint injuries (Behm et al., 2023; Read et al., 2016). Flexibility has a large effect size, which indicates that yoga might be the first option of flexibility training for basketball players, and the benefit may be more significant with yoga than with existing static and dynamic stretching exercises. Future research could also explore whether particular asanas are more suited to improving flexibility in areas where basketball players are at increased risk of injury (for instance, the hamstrings, hip flexors and shoulders).

Limitations

The study's findings are promising, but the research did have limitations. Due to only a sample size of 41 male basketball players, results are not generalizable to other demographics: female athletes or those in other sports. Moreover, this is also a 12-week session instead of following up on the benefits of continued yoga practice. Future research could follow interventions for longer periods and follow-ups to see the lasting effects of continued yoga practice. This standardized intervention may not adequately account for possible variations in an individual's fitness level; hence, individualized programs may result in better outcomes. Finally, the psychological benefit was not measured, which is as essential to the athlete's psychological resilience and focus. Yoga could also be the subject of future research to check whether it can be a holistic potential in sports to enhance physical and mental conditioning.

Future Recommendations

Future studies of this nature should involve larger samples made up of more diverse populations of athletes, including athletes from various sports, of different ages and both genders. In addition, the research could explore how the long-term benefits of practising yoga in fitness improve or plateau for continued benefits of the practice in fitness training. Furthermore, the effects of yoga on sport-specific performance metrics such as shooting accuracy, reaction time and agility, along with coupling psychological evaluations, will give a bigger picture of the impact of yoga on total sporting development. Lastly, personalized yoga programs that match an athlete's needs can bring maximal physical benefit with little injury risk, making yoga a commonly overlooked but valuable tool for high-performance athletes.

Conclusion

The results of this study show the effectiveness of yoga as a supplementary programme to the traditional training of basketball players with a marked improvement of CVE, MS, ME and FLE. Yoga is an attractive addition to an athlete's training program as an integrated component because it is a well-rounded approach to physical fitness that may improve performance, decrease the risk of injury, and contribute to mental resilience. Future research in various populations, an extended period of intervention, and sport-specific performance tests are needed, eventually leading to

yoga's inclusion as a staple component of modern athletic conditioning.

Conflict of interest

The authors declare that there is no conflict of interest.

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Підвищення рівня фізичної підготовленості баскетболістів-чоловіків через застосування йогічних асан: 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: 11 с., 3 табл., 2 рис., 38 джерел.

Історія питання. Зростаюча популярність занять йогою як додаткового методу тренувального процесу спричинила зацікавленість щодо вивчення її впливу на рівень фізичної підготовленості серед баскетболістів-чоловіків.

Мета дослідження. Це дослідження мало на меті оцінити вплив йогічних асан на показники фізичної підготовленості баскетболістів-чоловіків. Головне завдання дослідження полягало у визначенні ефективності практики йогічних асан на стан кардіореспіраторної витривалості (КРВ), м'язової сили (МС), м'язової витривалості (МВ) та гнучкості (ГНУ) у баскетболістів-чоловіків.

Матеріали та методи. У дослідженні взяли участь загалом 41 баскетболіст чоловічої статі, яких було розподілено за методом рандомізації на дві групи: група, що займалася виконанням йогічних асан (ЙАГ) у кількості 21 гравця (вік: $18,44 \pm 0,98$ років, зріст: $171 \pm 4,45$ см, вага: $87,94 \pm 4,26$ кг), та контрольна група (КОН), до якої увійшли 20 гравців (вік: $18,93 \pm 1,38$ років, зріст: $174 \pm 6,21$ см, вага: $91,31 \pm 7,00$ кг). Оцінка параметрів фізичної підготовленості проводилася на етапах перед та після завершення курсу дослідження.

Результати. Результати дослідження продемонстрували статистично значуще покращення показників фізичної підготовленості серед гравців ЙАГ, з рівнями р-значень менше за 0,05 для КРВ ($p < 0,001$), МС ($p < 0,001$), МВ ($p < 0,001$) та ГНУ ($p < 0,001$) після застосування практики йогічних асан. Натомість у контрольній групі суттєвих змін не спостерігалося ($p > 0,05$).

Висновки. Отримані дані експериментального дослідження дозволяють стверджувати, що впровадження йогівських асан у тренувальні програми сприяє значному поліпшенню параметрів фізичної підготовленості баскетболістів-чоловіків, що підкреслює потенційні переваги занять йогою як ефективної форми тренувального процесу.

Ключові слова: баскетболісти, йогічна асана, м'язова сила, м'язова витривалість, гнучкість.

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Modelling the Effectiveness of Recreational Physical Activities Focused on Improving Stress Tolerance in University Students During Wartime

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Abstract

Objectives. The present study aimed to evaluate the effectiveness of various health-enhancing recreational physical activity (PA) programs in the prevention of stress-related states in students during wartime.

Materials and methods. The study involved 125 university students, and used questionnaires comprising blocks of questions designed to ascertain psychophysiological indicators (activity, mood, sleep, appetite, performance, and well-being) with the 5-point Likert scale; stress level by Shcherbatykh; anxiety scores using the Spielberg-Hanin Inventory; and the risk of PTSD using the Mississippi Scale. To analyze the impact of different types of PA on stress-related states, logistic regression models were built. Additionally, GLZ models were used. The statistical significance of the models was assessed using the Wald test.

Results. The analysis indicated that adventure tourism is a statistically significant predictor ($p < 0.05$) of stress reduction, a decrease in heavy thoughts, and mood improvement. Mental fitness was found to be the most effective means for restoring mental balance. The models for predicting an increase in stress tolerance revealed dependencies on the type and amount of PA. This study contributes to the extant scientific knowledge base in the field of health-enhancing recreational physical activity aimed at preventing stress-related states. The proposed approach to the use of GLZ-models in the study of students' stress tolerance opens up new opportunities for analyzing the complex relationships between types of PA and psycho-emotional states.

Conclusions. The modelling results obtained allow for precise predictions regarding the effectiveness of different types of PA in the prevention of stress-related states among university students. The developed models can be used to generate individualized recommendations for physical activity, taking into account the unique needs, stress levels, and psycho-emotional state of students.

Keywords: students, adventure tourism, mental fitness, team sports, prevention, stress-related state, modelling, effect.

Introduction

Today's Ukrainian university students are exposed to military stressors for a long time (Andrieieva et al, 2023). They experience a significant psychological stress as a result

of constant anxiety, fear for their lives and health, instability, and economic disruption caused by military operations (Byshevets et al, 2023; Rybalko et al, 2024). These factors lead to widespread stress-related states among students, such as stress, anxiety, and the risk of developing post-traumatic stress disorder (PTSD) (Petrachkov et al, 2023).

Currently, there is a significant body of research that supports the effectiveness of physical activity (PA) in preventing stress-related states among university students (Ai et al, 2021; Bramwell et al, 2023; Gerber et al, 2014).

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However, there is currently limited information on the effectiveness of PA in preventing stress-related states in university students during wartime (Byshevets et al, 2023; Skaliy et al, 2024).

Researchers consider this category of students to be highly susceptible to stress (Fuente et al, 2018; Byshevets et al, 2023; Rybalko et al, 2024). Transitioning to independent living, adjusting to a new team and the demands of an educational institution, building relationships with classmates and teachers, increased academic workload, tests, exams, project work, and financial problems can all cause increased stress. Therefore, researchers are interested in determining which types of PA are most beneficial in preventing stress-related states in university students. Among the most effective types of PA, researchers mention mental fitness (Ahmed et al, 2021; Andrieieva et al, 2024) and physical exercise with music (Hanna, 1995), group exercise (Reed, Ones, 2006; Hakman et al, 2020; Mulyk et al, 2024), and adventure tourism (Kaplan, 1995; Holland et al, 2018; Ewert, Yoshino, 2011; Andrieieva et al, 2022, 2024; Mulyk et al, 2024). In addition, there is a growing body of research that provides strong evidence of a positive relationship between the effects of nature observation, outdoor walking, and recovery from stress (Van den Berg, 2010; Byshevets, Andrieieva, et al, 2024).

According to Holland et al (2018), recreational activities help improve mood in 67 % of cases, reduce stress in 64 %, increase self-esteem in 63 %, reduce depression in 62 %, improve concentration in 61 %, improve memory in 60 %, and improve cognitive function in 59 %. According to Ewert, Yoshino (2011), participation in short-term outdoor adventure programs prevents the development of stress in students, helps to increase their stress tolerance, and has a long-term effect that lasts for 2-3 years.

Researchers (Ahmed et al, 2021) demonstrated that three Pilates sessions per week for six weeks reduced academic stress in university students. Furthermore, Hanna (1995), who considers dance classes as physical exercises with a strong emotional coloration, emphasizes their exceptional effectiveness compared to other physical exercises. According to the author, dancing improves mood, reduces pain, distracts from problems, releases negative energy, create a feeling of pleasure and euphoria, and helps to overcome or mitigate the deleterious effects of stress factors. As for team sports, researchers have repeatedly emphasized the benefits of group classes, which are important because loneliness can lead to problematic behaviors in university that may include problem avoidance, wishful thinking, social isolation, and self-criticism (Fuente et al, 2018) In addition, Bramwell et al (2023) believe that outdoor group exercise can help prevent stress-related states in students.

The hypothesis of this study is that positive stress, which occurs during PA and is associated with a sense of challenge, goal achievement, and vitality, can serve as a compensatory or minimizing factor for the long-term negative stress experienced by students in the context of Russian armed aggression against Ukraine. This positive stress can act as a preventive measure against stress-related states, such as stress, anxiety, and the risk of developing PTSD. Furthermore, it is hypothesized that higher loads and risk elements typical of such activities as adventure tourism can enhance this effect, especially under the impact of intense

stressors. Positive experiences associated with overcoming difficulties, such as increased self-esteem, improved mood, and feelings of satisfaction, have been shown to mitigate symptoms of chronic stress and promote psycho-emotional health.

The issue of military stressors and their impact on university students, along with potential solutions that involve PA, is a pertinent one that warrants attention.

The objective of the study was to evaluate the effectiveness of various health-enhancing recreational physical activity programs in the prevention of stress-related states among students during wartime.

Materials and Methods

Participants

The sample included three groups of students who participated in different types of PA during the year (from October 2023 to September 2024). In total, the study involved 125 university students living and studying in Ukraine. The first group consisted of 46 students who participated in outdoor activities and took part in short-term outdoor adventure programs organized in Ukraine during the specified period. Of these students, 65.2 % were male and the remainder were female. The second group consists of 32 students who participated in team sports (volleyball, basketball). Of these, 78.1 % were male. The third group comprised 47 students who participated in mental fitness activities during the study, with 72.3 % of them being female.

The following inclusion criteria were applied: students aged 18 to 25 years old who were enrolled in higher education institutions in Ukraine; written voluntary consent to participate in the study; permanent residence in Ukraine throughout the study period; participation in regular classes in the relevant type of physical activity (adventure tourism, team sports, mental fitness) at least twice a week throughout the year; no serious medical contraindications to participate in the selected type of physical activity.

The exclusion criteria were as follows: the presence of chronic diseases or injuries that limit one's ability to engage in regular physical activity; failing to attend more than 20% of the planned training during the study; participation in other types of physical activity that could significantly affect the results of the study; refusal to participate in the study at any stage; failure to provide complete and accurate responses in questionnaires or other research documents. The implementation of these inclusion and exclusion criteria was intended to ensure the homogeneity of the sample and enhance the reliability of the results.

This study was conducted in accordance with the international ethical standards stipulated in the Declaration of Helsinki, as adopted by the World Medical Association. This included adherence to the principles of respect for human rights, ensuring the safety and well-being of participants, and transparency of the information collection process. The participants were provided with exhaustive information regarding the objectives of the study, the methods to be employed, the potential risks, and the potential benefits of participating. They also provided voluntary written consent to take part in the study. The personal data of the respondents was kept confidential and used exclusively for

research purposes. In the interest of protecting the privacy of the subjects, all data were anonymized. The organization of the study ensured that any discomfort or possible negative impact on the physical or mental health of the participants was minimized. The results are based exclusively on the data collected and do not contain any subjective interpretations.

Research Organization

The study utilized questionnaires comprising blocks of questions designed to ascertain psychophysiological indicators (activity, mood, sleep, appetite, performance, and well-being, measured with the 5-point Likert scale from 1 (very poor) to 5 (very good)); Cronbach's alpha – 0.863); stress level was assessed by Shcherbatykh; anxiety scores were evaluated using the Spielberg-Hanin Inventory and the risk of PTSD using the Mississippi Scale. Improvements that could occur under the influence of PA classes and factors that can mitigate the impact of military stressors (adventure tourism / game sports / mental fitness) were measured with a categorical scale. The primary objective of these programs was the prevention of stress-related states during wartime. The following program parameters were common: frequency twice a week; duration 80 minutes; and medium intensity.

Statistical Analysis

The use of descriptive statistics was preceded by testing the hypothesis of a normal distribution of the input data using the Shapiro-Wilk W test. In the absence of confirmation of these hypotheses, the measures of the central tendency and scatter of the studied indicators were presented using the median Me and the 1st and 3rd quartiles, which are less sensitive to outliers and deviations from a normal distribution. The data were presented in the form of Me (25%; 75%). To make a comparison between the characteristics of students engaged in different types of PA, a ranked analysis of variance was used, with the calculation of the Kruskal-Wallis H-criterion. Multiple comparisons were conducted, with *-values* being calculated, and the resulting data being evaluated against the critical value of the *z*-statistic, which is 1.96 for a significance level of 0.05.

The use of generalized linear and nonlinear models to predict improvements in students' well-being. To analyze the impact of different types of PA on stress-related states, logistic regression models were built to model the probability of improvement as a function of independent variables. GLZ models were used, which combine linear and nonlinear elements into a single structure, making the model flexible and suitable for a wide range of tasks (Shynkaruk, Byshevets, et al, 2025). This approach enables the analysis of both quantitative (e.g., stress, anxiety, PTSD risk) and qualitative (e.g., student groups, sex) data, incorporating both linear and nonlinear relationships between these variables. The utilization of these models enables the consideration of additional factors that may influence the dependent variable. It is noteworthy that the incorporation of a count variable within the model (in this instance, the number of stress-associated states) resulted in the statistical significance of certain variables that were previously deemed insignificant. This was made possible by reducing the standard errors and enhancing the model fit, which enabled the estimation of the effects of other variables with greater precision. Consequently, a multitude of variables have attained statistical significance at the 0.05 level, signifying a more accurate evaluation of their impact.

The Table 1 provides a detailed description of the variables utilized in the modeling process.

It is important to acknowledge that in earlier stages of the modeling process, sex was regarded as an independent categorical variable. However, in this case, statistical problems emerged in the models, which led to incorrect outcomes. Specifically, we found a lack of pivotal elements in the design matrix, which indicates a linear relationship between the predictors or multicollinearity. In addition, the distribution of the "sex" variable across the study groups was found to be imbalanced.

Given that the exclusion of the "sex" variable from the model did not result in a significant reduction in model quality, it was decided to exclude this variable from further analysis. This decision resulted in more stable and interpretable models.

The statistical significance of the models was then assessed using the Wald test. The quality of the models was evaluated using the following indicators:

Table 1. Description of the input data

	Parameter / Type	Description	Value range	Encoding
Dependent	binary	Stress reduction	Occurred / did not occur	1/0
		Management of heavy thoughts	Occurred / did not occur	1/0
		Restoration of mental balance	Occurred / did not occur	1/0
		Mood improvement	Occurred / did not occur	1/0
		Improved stress tolerance	Occurred / did not occur	1/0
Independent	continuous	Psychophysiological state, points	6 – 30	no encoding
		Stress, points	0 – 66	no encoding
		Anxiety, points	20 – 60	no encoding
		Risk of PTSD, points	39 – 195	no encoding
		PA, points	0 – 49	no encoding
	categorical	Group	1, 2, 3	no encoding
	Countable / ordinal	Number of stress-related states	0-4	no encoding

- Accuracy is an indicator that reflects the overall accuracy of classification, i.e. the extent to which the model correctly classifies each data sample.
- Recall is a metric that indicates the ability of a model to detect all relevant cases.
- Precision is a measure of specificity that shows what proportion of samples classified as positive by the model are actually positive. The maximum Precision value (0.88) was documented for the “Mood Improvement” model, indicating its high specificity.

The F1-score is a harmonic mean of Precision and Recall, which assess the overall balance of a model.

The level of statistical significance was 0.05 ($p < 0.05$). Calculations were performed using STATISTICA software (StatSoft, USA).

Results

In the course of the study, we examined the central tendency and the scatter of students' scores depending on the type of PA they were engaged in.

The adventure tourism group exhibited the lowest stress and PTSD risk scores. Furthermore, the highest levels of PA were observed among students participated in adventure tourism activities. The data obtained revealed that students' anxiety scores remained consistent with the lowest prevalence of stress-related states observed among those engaged in team sports (Table 2).

It was found that among the positive changes, the respondents most often indicated an improvement in mood: 80.4% of students participated in adventure tourism activities indicated this. With a lower frequency, students reported restoration of mental balance, where the highest results were observed among students engaged in choreography with elements of mental fitness (Fig. 1).

The data obtained was used to built logistic models that enabled the prediction of an improvement in students' state based on the studied parameters, including the type of PA.
 $Stress = 24.47 + 3.84x_1 + 0.6x_2 + 0.05x_3 - 0.47x_4 + 0.51x_5 + 0.6x_6$
 $Anxiety = 49.3 + 0.51x_1 - 0.2x_2 - 0.09x_3 - 0.88x_4 + 0.37x_5 - 0.17x_6$
 $Risk\ of\ PTSD = 121.8 + 0.8x_1 - 0.55x_2 - 0.71x_3 - 6.72x_4 - 4.09x_5 + 2.7x_6$,
 where x_1 is stress-related state; x_2 is psychophysiological state; x_3 is a physical activity level; x_4 is bad habits; x_5 is bad habits in group 1; x_6 is bad habits in group 2.

Table 2. The central tendency and the scatter of the studied parameters (n = 125)

Parameter	Group 1 (n = 46)			Group 2 (n = 32)			Group 3 (n = 47)		
	Me	25 th percentile	75 th percentile	Me	25 th percentile	75 th percentile	Me	25 th percentile	75 th percentile
Stress-related states, number	1.0*	0.0	2.0	0.0**	0.0	2.0	2.0	1.0	2.0
Psychophysiological state, points	23.0	19.0	26.0	22.5	19.0	24.0	22.0	18.0	25.0
Stress, points	14.0	9.0	22.0	15.0	6.5	23.3	18.0	13.0	30.0
Anxiety, points	44.0	41.0	46.0	42.0	40.0	46.0	43.0	41.0	45.0
Risk of PTSD, points	75.0*	69.0	89.0	81.5	69.5	97.0	83.0	75.0	100.0
PA, points	36.0	31.0	40.0	34.5	30.0	40.5	35.0	28.0	39.0

Notes: * – statistically significant differences between students of groups 1 and 3; ** – statistically significant differences between students of groups 2 and 3

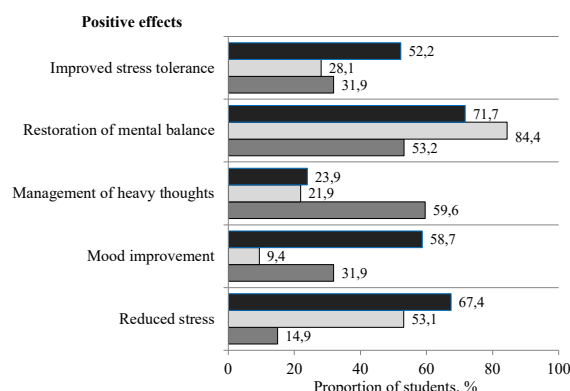


Fig. 1. Positive changes in students well-being under the influence of participation in different types of PA (n = 125). ■ – adventure tourism; □ – team sports; ▒ – choreography with mental fitness

Table 3 presents the estimates of the regression parameters, which are interpreted through the odds ratio. When the odds ratio exceeds 1, an increase in the value of the relevant predictor (e.g., anxiety) leads to an elevated probability of no improvement. Conversely, if the odds ratio is less than 1, an increase in the value of the predictor decreases the chances that the improvement will not occur. The reference group in this study comprised students who were engaged in choreography with elements of mental fitness.

The following conclusions can be drawn from the analysis of the coefficients of the “Stress reduction” model:

- an increase in the stress score by 1 point is associated with an increase in the probability of no stress reduction by almost 14 % ($EXP(0.13) - 1 \approx 0.139$);
- an increase in anxiety score by 1 point allows for the prediction of a decrease in the probability of stress reduction in the student by 24.6 % ($(EXP(0.22) - 1) \approx 24.6\%$);
- a decrease in the psychophysiological state reduces the probability of stress reduction by 22.9 % ($(1 - EXP(-0.26)) - 1 \approx 22.9\%$);
- participation in adventure tourism activities was found to reduce the probability of no improvement by 87.5 % ($(1 - EXP(-2.08)) \approx 87.5\%$).

Table 3. Parameter estimates. Modeled probability that no improvement occurs (n = 125)

Effect		Distribution : BINOMIAL, Link function: LOGIT					
		Estimate	Standard Error	Wald Stat.	Lower CL 95, %	Upper CL 95, %	p
Stress reduction (Wald $\chi^2 = 28.29$, $p < 0.05$)	Intercept	-7.89	5.20	2.299	-18.09	2.31	0.1294
	Psychophysiological state, points	-0.26*	0.08	10.235	-0.43	-0.10	0.0014
	Stress	0.13*	0.04	10.475	0.05	0.22	0.0012
	Anxiety	0.22*	0.09	5.371	0.03	0.40	0.0205
	Risk of PTSD	-0.01	0.02	0.197	-0.04	0.03	0.6568
	PA, points	0.09	0.05	3.593	-0.00	0.18	0.0580
	Group (1)	-2.08*	0.47	19.568	-3.01	-1.16	<0.05
	Group (2)	-0.34	0.44	0.604	-1.19	0.52	0.4371
Management of heavy thoughts (Wald $\chi^2 = 10.03$, $p = 0.0066$)	Intercept	-14.15*	4.66	9.221	-23.28	-5.02	0.0024
	Psychophysiological state, points	-0.09	0.05	2.956	-0.20	0.01	0.0856
	Stress	-0.02	0.02	0.672	-0.06	0.03	0.4124
	Anxiety	0.15	0.08	3.698	-0.00	0.30	0.0545
	Risk of PTSD	0.12*	0.02	28.600	0.08	0.16	<0.05
	PA, points	0.05	0.04	1.494	-0.03	0.12	0.2215
	Group (1)	-1.47*	0.47	10.024	-2.39	-0.56	0.0015
	Group (2)	1.97*	0.75	6.863	0.50	3.45	0.0088
Restoration of mental balance (Wald $\chi^2 = 29.92$, $p < 0.05$)	Intercept	-2.34	4.00	0.343	-10.18	5.50	0.5583
	Psychophysiological state, points	-0.16*	0.07	5.574	-0.29	-0.03	0.0182
	Stress	0.20*	0.04	24.850	0.12	0.28	<0.05
	Anxiety	0.05	0.07	0.621	-0.08	0.18	0.4305
	Risk of PTSD	0.01	0.01	0.686	-0.02	0.04	0.4074
	PA, points	0.01	0.04	0.075	-0.07	0.09	0.7842
	Group (1)	1.52*	0.54	8.102	0.47	2.57	0.0044
	Group (2)	1.32*	0.65	4.128	0.05	2.60	0.0422
Improved mood (Wald $\chi^2 = 7.78$, $p = 0.0205$)	Intercept	13.60*	4.06	11.239	5.65	21.55	0.0008
	Psychophysiological state, points	0.01	0.05	0.068	-0.09	0.12	0.7946
	Stress	-0.00	0.03	0.028	-0.06	0.05	0.8676
	Anxiety	-0.05	0.06	0.743	-0.18	0.07	0.3887
	Risk of PTSD	0.01	0.02	0.737	-0.02	0.05	0.3905
	PA, points	-0.38*	0.06	34.638	-0.51	-0.26	<0.05
	Group (1)	-1.09*	0.42	6.609	-1.93	-0.26	0.0101
	Group (2)	0.38	0.44	0.760	-0.47	1.23	0.3833
Improved stress tolerance (Wald $\chi^2 = 3.68$, $p = 0.1587$)	Intercept	17.88*	5.01	12.736	8.06	27.70	0.0004
	Psychophysiological state, points	-0.32*	0.08	15.178	-0.49	-0.16	0.0001
	Stress	-0.05	0.03	3.534	-0.11	0.00	0.0601
	Anxiety	0.01	0.06	0.031	-0.11	0.14	0.8595
	Risk of PTSD	0.01	0.02	0.335	-0.02	0.04	0.5626
	PA, points	-0.29*	0.06	24.759	-0.41	-0.18	<0.05
	Group (1)	-0.71	0.39	3.342	-1.47	0.05	0.0675
	Group (2)	0.86	0.50	2.948	-0.12	1.84	0.0860

Note: * – coefficient is statistically significant at the p-level of 0.05

The findings suggest that the level of stress, anxiety, and psychophysiological state exerts a substantial influence on the probability of stress reduction in students. Furthermore, the most significant predictor is the type of PA. Specifically, participation in adventure tourism (Group 1) was found to have a substantial impact on the probability of stress reduction. The study also identified other statistically

significant factors, including a negative impact of the levels of stress and anxiety on stress reduction, and a statistically significant negative effect ($p < 0.05$) of a decrease in psychophysiological state on stress reduction.

To illustrate, a hypothetical student with a psychophysiological state, stress, and anxiety scores of 25, 10, and 40 points, respectively, who engaged in adventure tourism

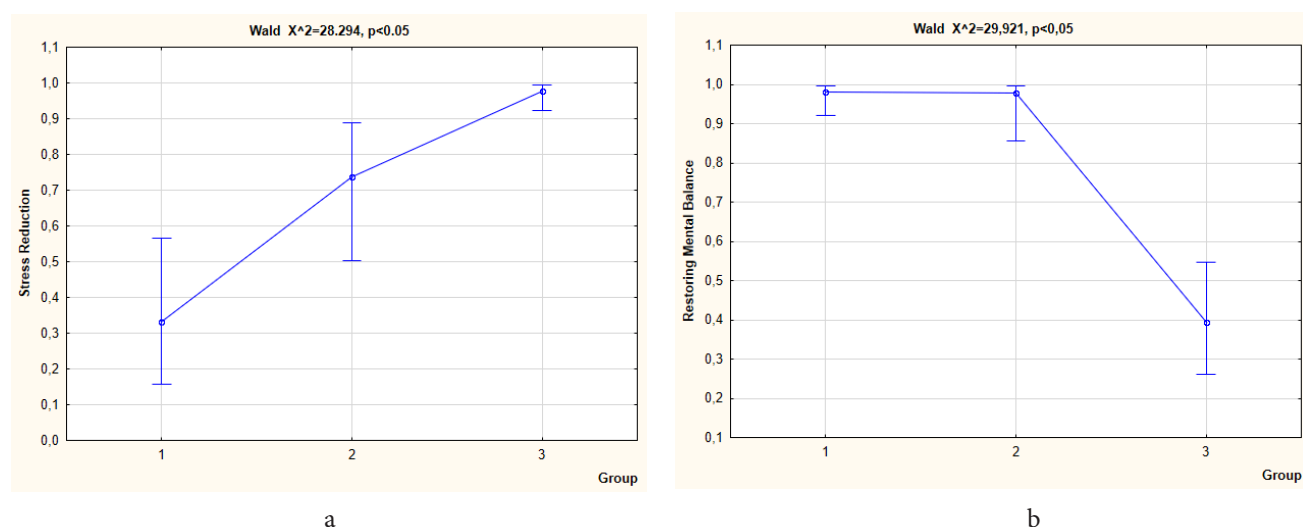


Fig. 2. Probability of no positive effect: a – stress reduction; b – restoration of mental balance

would have an 82.1 % probability of not experiencing stress reduction. However, when engaging in other forms of PA, this probability increases to 97.3 %. Improving the psychophysiological state to 30 points results in a probability of no stress reduction of 55.5 % when participating in adventure tourism and 90.9% when engaging in other types of PA.

The results of the model built using the Wald criterion ($\text{Wald } \chi^2=28.29; p<0.05$) indicate that the type of PA has a statistically significant ($p<0.05$) effect on stress reduction in students. Concurrently, other variables, such as psychophysiological state, stress, and anxiety, were considered as covariates, which allowed us to control their influence and isolate the individual effect of the type of PA. In a similar vein, we built and examined the models for the restoration of mental balance, mood improvement, and improved stress tolerance. Our findings indicated that adventure tourism is more effective in stress reduction, management of heavy thoughts, and mood improvement. On the other hand, choreography with elements of mental fitness is more effective in the restoration of mental balance in comparison to team sports (Fig. 2). The impact of PA on stress tolerance is not specific to its type, but rather contingent on its volume.

Therefore, it was demonstrated that participation in adventure tourism contributes to the stress reduction, the management of heavy thoughts, and mood improvement. Furthermore, choreography with elements of mental fitness is more effective in restoring mental balance.

The quality assessment of the models demonstrated that they possess high predictive capabilities. Specifically, the Accuracy score ranges from 0.83 for the “Restoration of balance” model to 0.91 for the “Stress Reduction” model. The “Mood Improvement” model demonstrated the maximum value of Recall (0.84), while the “Restoration of balance” model had the minimum values (0.72). The highest value of Precision (0.88) was recorded for the model “Mood Improvement”, and the lowest (0.73) was observed for the model “Restoration of Balance”. A similar trend was observed for the F1 score, with the maximum value (0.86) recorded for the “Mood improvement” model and the minimum value (0.73) for the “Restoration of Balance” model (Table 3).

The quality assessment of the models demonstrated their capacity to predict the improvement in various criteria. The most accurate models were those that predicted “Mood improvement” and “Stress reduction”. These models exhibited

Table 4. Matrices of classification and quality assessment of the models

The built models	Class Observed	Class Predicted		Indicators of model quality			
		0	1	Accuracy	Recall	Precision	F1 Score
Stress reduction	Observed 0	111	7	0.91	0.81	0.83	0.82
	Observed 1	8	35				
Management of heavy thoughts	Observed 0	94	13	0.85	0.80	0.77	0.78
	Observed 1	11	43				
Restoration of mental balance	Observed 0	98	13	0.83	0.72	0.73	0.73
	Observed 1	14	36				
Mood improvement	Observed 0	71	9	0.86	0.84	0.88	0.86
	Observed 1	13	68				
Improved stress tolerance	Observed 0	92	12	0.86	0.81	0.79	0.80
	Observed 1	11	46				

high values across all metrics evaluated, including Accuracy and F1-Score. The “Restoration of Balance” model exhibited slightly lower performance metrics; however, its predictive capability is also was high. The results obtained indicate the effectiveness of the built models for predicting the impact of different types of physical activity on psychological state.

Discussion

The findings on the effectiveness of various physical activities in alleviating stress-related states among students corroborate extant research conclusions on the substantial impact of physical activity on the mental well-being (Martín-Rodríguez et al 2024; Rybalko et al, 2024; Steinacker et al, 2023). Studies conducted by Biggs et al (2017) underscore the pivotal role of adaptive mechanisms, including physical activity, in the process of stress management. The studies (Reed & Ones, 2006; Gerber et al., 2014) emphasize that the type and context of PA are important for the effectiveness of its impact on the psycho-emotional state. Logistic models were built to predict the overcoming of stress-associated states in students based on data on the types of PA they are engaged in. A comparative analysis of these models reveals that the model designed to predict improved stress tolerance is the only one that does not incorporate the group variable. This observation indicates that the specific type of PA does not influence the extent of the improvement in stress tolerance among students.

Despite the fact that the students engaged in team sports activities demonstrated superior outcomes, elevated estimates of their risk of developing PTSD served to nullify the impact of other variables, thereby precluding them from exhibiting enhancements in the likelihood of stress reduction, management of heavy thoughts, restoration of mental balance, and mood improvement. The absence of a beneficial impact of team sports on stress tolerance may be ascribed to the elevated levels of competition and emotional distress that are hallmarks of these activities (Weinberg & Gould, 2019). As Weinberg and Gould (2019) indicated, elevated cortisol levels resulting from competitive sports activities have the potential to hinder the body's capacity for psychological recovery. Conversely, the superior outcomes observed in the mental fitness group may be attributable to the influence of hidden factors that were not directly reflected in the original data but play a pivotal role in the modeling.

The findings for the mental fitness and adventure tourism groups are consistent with research showing that less competitive activities, such as yoga or nature-based outdoor sports, contribute to lower levels of anxiety, depression, and general stress (Park et al., 2010; Berman et al., 2008). These activities often provide more opportunities for social support, self-reflection, and emotional recovery, which is supported by the findings of Biddle and Mutrie (2008).

The superior outcomes demonstrated by the adventure tourism group may be attributable not only to the inherent characteristics of the activity itself, but also to the influence of hidden factors. As Kaplan (1995) observes in his theory of restorative environments, exposure to nature exerts a beneficial influence on cognitive and emotional processes. The elements of adventure tourism, such as interaction with nature, social cohesion in the group, and a sense of achievement, have the potential to play a key role in the process of coping with stress.

While the models built were statistically significant, they indicated the need for improvement by expanding

the sample to include different types of PA and more balanced consideration of sex-related characteristics. This recommendation aligns with the growing call for personalized approaches to physical activity as a means to manage stress (McEwen & Wingfield, 2003).

Furthermore, the unique challenges posed by wartime conditions necessitate the development of effective coping mechanisms to support students' mental well-being. The findings of this study underscore the necessity to integrate less competitive and more inclusive activities into PA programs aimed at the prevention of stress-related states. In particular, adventure tourism and mental fitness can serve as foundational elements of these programs. It is imperative to integrate less competitive activities into educational programs, particularly those that promote emotional engagement and social support. The development of adapted PA programs catering to diverse social and sex groups, with consideration for their unique needs in high-pressure circumstances, is also crucial. Further study of hidden factors, such as the impact of social cohesion, emotional support, and interaction with nature, is necessary to improve the effectiveness of prediction models. This study is among the first to examine the impact of different types of PA on the stress-related states among university students during wartime, thereby contributing to a more nuanced understanding of the mechanisms through which adventure tourism impacts the stress-related states in students.

Conclusions

This study demonstrated the effectiveness of PA interventions in mitigating stress-related states among university students during wartime. The study confirmed that the selected type of PA has a significant impact on the students' ability to overcome stress-related states. The findings emphasize the efficacy of less competitive activities, such as mental fitness and adventure tourism, in fostering a secure and nurturing environment conducive to emotional recovery. The lowest stress scores were found for the students of the Group 2, who participated in team sports, and the lowest risk of PTSD was observed in the students of the Group 1, who engaged in short-term outdoor adventure programs. Our findings indicate that adventure tourism is more effective in stress reduction, management of heavy thoughts, and mood improvement. Furthermore, the impact of mental fitness programs on the ability to manage heavy thoughts was more pronounced than that of team sports activities. The findings also reveal that adventure tourism exerts a more pronounced effect on students' perception of the military stressors. This phenomenon can be attributed to the substantial physical and mental loads associated with this type of activities, as well as the heightened emotional intensity experienced in comparison to other types of PA.

Limitations of the study. The use of self-reports can introduce a certain degree of subjectivity in the data, as participants may perceive and interpret their states differently.

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Conflict of Interest

The authors declare no conflict of interest.

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Моделювання ефективності рекреаційної фізичної активності, спрямованої на підвищення стресостійкості студентів університету в умовах війни

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

Реферат. Стаття: 10 с., 3 табл., 2 рис., 38 джерел.

Мета дослідження – оцінити ефективність впливу різних програм оздоровчо-рекреаційної рухової активності у профілактиці стрес-асоційованих станів у студентів в умовах воєнного часу.

Матеріали та методи. У дослідженні взяли участь 125 здобувачів вищої освіти. Використано анкети, що містили блоки питань, спрямовані на визначення: психофізіологічних показників (активність, настрій, сон, апетит, працездатність, самопочуття; вимірювання – 5-бальна шкала Лайкерта від 1 (дуже погано) до 5 (дуже добре); альфа Кронбаха – 0,863); оцінки стресу, тривоги за опитувальником Спілберга-Ханіна; ризику ПТСР за Місісіпською шкалою. Для аналізу впливу різних видів рухової активності на стрес-асоційовані стани було побудовано логістичні регресійні моделі. Використано GLZ-моделі. Статистична значущість моделей перевірялася з допомогою критерію Вальда.

Результати. Аналіз показав, що пригодницький туризм є статистично значущим предиктором ($p < 0,05$) для прогнозування зниження рівня стресу, зменшення нав'язливих думок і покращення настрою, ментальний фітнес виявився найбільш ефективним для відновлення психічного стану. Моделі прогнозування підвищення стресостійкості виявили залежності від виду та обсягу рухової активності. Дослідження доповнює сучасну наукову базу знань у сфері оздоровчо-рекреаційної рухової активності, спрямованої на профілактику стрес-асоційованих станів. Запропонований підхід до використання GLZ-моделей у дослідженні стресостійкості студентів відкриває нові можливості для аналізу складних залежностей між видами рухової активності та психоемоційними станами.

Висновки. Результати моделювання дозволяють з високою точністю прогнозувати ефективність різних видів рухової активності для профілактики стрес-асоційованих станів у здобувачів вищої освіти. Отримані моделі можуть бути використані для розробки персоналізованих рекомендацій щодо рухової активності для студентів з урахуванням їхніх індивідуальних потреб, рівня стресу та психоемоційного стану.

Ключові слова: студенти, пригодницький туризм, ментальний фітнес, ігрові види, профілактика, стрес-асоційований стан, моделювання, ефект.

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Developing a Target Games-Based Long Service Training Model in Badminton for Beginner Athletes

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Abstract

Background. The development of long service skills in badminton is one of the important components to improve game performance. The low variety of badminton long service training models is considered as a problem in training beginner players, which has an impact on the mastery of this technique.

Objectives. This study aimed to develop and determine the effectiveness of a long service training model based on target games in enhancing the long service skills of beginner badminton players.

Materials and methods. The research design used was a research and development method by following the Borg & Gall model, involving ten stages ranging from needs analysis to effectiveness testing. The research subjects were beginner players at the Faculty of Sport Sciences, Medan State University, with a sample of 42 players divided into experimental and control groups. Data collection used a pre-experimental pretest-posttest design. Data analysis was assisted by the SPSS application and used the paired-sample t-test and independent samples t-test.

Results. Based upon the validation results, 18 variations of exercise models were deemed feasible for large-scale trials with an average feasibility percentage of 77 %. These outcomes were obtained after minor revisions based on suggestions to increase the intensity and duration of the exercises. However, the models were overall deemed feasible without significant changes. The results showed a substantial difference between the group using the target games-based training model and the group using the conventional training model ($p < 0.05$). The target games-based training model has proved to be more effective in improving the long service ability of beginner players.

Conclusions. According to the findings, it can be concluded that the target games-based long service training model provides significant efficacy in improving the long service skills of beginner players. This model is also considered feasible to be applied more widely in coaching beginner badminton players.

Keywords: training model, badminton, long service, beginner athletes, target games.

Introduction

Badminton is one of the most popular sports because it is easily played by children, teenagers and adults (Cabello-Manrique et al., 2022). This badminton game can be played using a racket and a small ball called a shuttlecock either in single, double, mixed double or mixed double (Liu et al., 2020). As according to Ardiantoro & Sunarmi, (2020) that

badminton is a sport that is favoured by various levels of society ranging from early childhood to the elderly, both men and women. Then according to Soemardiawan et al., (2019) There are many reasons why badminton is popular, for example, it can improve physical and mental health, has a fairly low risk of injury, is easy to play, the rackets used are very durable and most importantly, all ages can play this sport. It can be played by everyone from children to the elderly, both male and female players (Kusnadi et al., 2019). Furthermore, according to Santoso et al., (2019) stated that Indonesia is one of countries which has achievements in world level badminton sports. Indonesia is one of countries which has achievements in world level badminton sports (Sholicha & Wahyudi, 2022).

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Achievements in badminton are achieved because athletes can play badminton well. According to Edmizal & Maifitri, (2021) stated that in order for someone to play badminton well, each individual must be able to hit the shuttlecock from above and from below. The types of shots that must be mastered include service, lob, dropshot, long service, netting, underhand and drive (Ma et al., 2021). Thus, long service and dropshot shots are basic techniques that must be mastered by a badminton player or athlete (Singh & Mishra, 2020). As according to Ayuningrum et al., (2021) that this long service also has an important role in singles play.

Long serve shots are often made by players in competing in singles games (Ruslan et al., 2021). This long service shot is difficult for beginners because they have to hit the shuttlecock as high as possible and fall near the back line of the opponent's court (Suryadi et al., 2023). Efforts made by the coach to master this long service shot by practicing long service with difficult targets and individually and alternately (Aini et al., 2023). So, the visible effect of the results of beginner long service shots is still low, and the variety of training models used by the coach is also still minimal, causing boredom and boredom during training (Bimantara et al., 2022). As said Suryadi et al. (2023) stated that for sports activities that have minimal elements of variation will make athletes quickly feel bored in doing so. Boredom in training will be detrimental to the progress of his achievements. Therefore, to eliminate boredom and boredom when practicing while at the same time being able to improve the results of beginner long service shots must have an element of variation in many training models (Ismik, 2022). The variety of training models to be created must also be interesting, easy to implement and can eliminate boredom (Herman, 2019). Variations of training models for long service hitting abilities planned by researchers in the form of training models based on target games (Gultom, 2019). The target game that will be delivered has a new nuance that aims to improve the ability of basic techniques of long service shots for beginner players (Ruslan et al., 2021).

Thus, the variation of badminton long service training model based on target/target games is believed to be suitable to be trained in badminton long service training for students who practice badminton at FIK Unimed. As said Ramadhan & Hidasari, (2020) that there is an effect of target games training on the accuracy of the backhand short serve of badminton extracurricular participants. Likewise according to Hromčík et al., (2019) Target games have an influence on the accuracy of forehand style serves. Thus, the target games-based badminton long service training model can be used as a solution to overcome the above problems. Variations of the training model will be packaged by considering the knowledge and abilities of beginners. Based on this background, this research is focused on researching the development of a target game-based badminton long service training model (target games) to improve the ability of beginner players' badminton long service shots.

Materials and Methods

Study Participants

The target population for this research is all students who practice badminton, especially taking badminton courses. The research subjects for the small-scale test were

12 people and 34 subjects for the large-scale trial. The Effectiveness Trial was 84 subjects consisting of 42 subjects for the experimental group and 42 subjects for the control group.

Table 1. Sample in research

Group	Number of Subjects	Indicator
Small Scale Test	12	1th Semester Students
Large Scale Test	34	1th Semester Students
Experiment Group	42	3th Semester Students
Control Group	42	5th Semester Students

Organization Studies

The design used in this research is the Research and Development (R & D) method (Purba et al., 2024; Tanri et al., 2023). The development of the long service training model is based on 10 (ten) stages, consisting of the results of needs analysis, planning, expert validation, small scale test, small scale test revision, large scale test, large scale test revision, effectiveness test, effectiveness test revision, and dissemination of research results.

In practice, the development of the badminton long service training model developed has 3 stages, namely: (1) an easy category stage training model consisting of 6 training models with floor value and the shuttlecock must pass through a rope stretched 2.05 metres high using 2 (two) poles placed parallel to the front service line; (2) a medium category stage training model consisting of 6 training models with a floor value target and the shuttlecock must pass through a rope stretched 2.30 metres high using 2 poles placed 1.5 metres from the front service line; (3) a difficult category stage training model consisting of 6 training models with a floor value target and the shuttlecock must pass through a rope stretched 2.55 metres high using 2 poles placed 3 metres from the front service line. The following is a picture of the field design in conducting the initial test and final test for long service and dropshot shots.

Instruments

The instrument to test the ability of badminton long service, the researcher uses a badminton long service ability test which is guided by the opinion of the researcher Singh & Mishra, (2020), namely by doing 10 long service shots. In addition, researchers collected data using questionnaires, interviews and documentation.

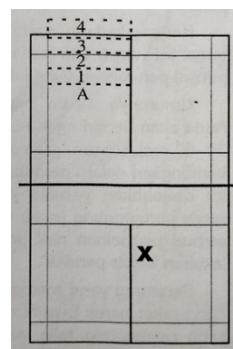


Fig. 1. Initial test and final test for long service

Table 2. Scoring of badminton long service test assessment

Badminton Long Service Test Scoring						
Name		:				
Class		:				
School		:				
Keterangan : Berilah Tanda Centang (√) pada Kolom Nilai Jatuhnya Shuttlecock						
No	Long Service Test	Shuttlecock Fall Value				Acquisition Value
		1	2	3	4	
1	Long Service Test 1					
2	Long Service Test 2					
3	Long Service Test 3					
4	Long Service Test 4					
5	Long Service Test 5					
6	Long Service Test 6					
7	Long Service Test 7					
8	Long Service Test 8					
9	Long Service Test 9					
10	Long Service Test 10					
Total Value						

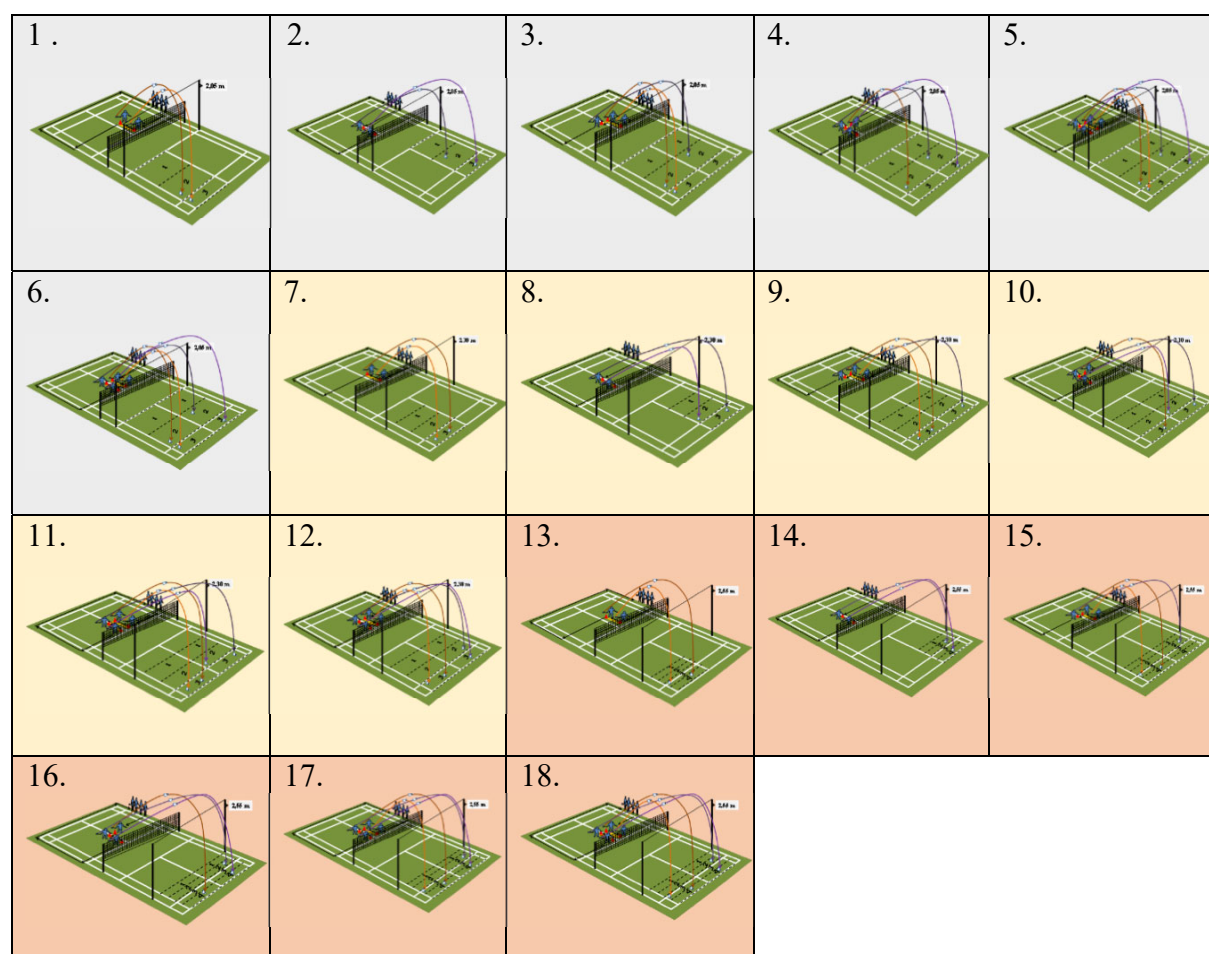
**Fig. 2.** 18 variations of long service training models

Table 3. Recapitulation of expert assessment results

Badminton Expert					
No	Indicators	Σx	Σxi	%	Description
1	Feasibility	56	72	78	worth
2	Ease	55	72	76	worth
3	Safety	57	72	79	worth
4	Attractiveness	57	72	79	worth
Total		225	288	78	worth
Coaching Expert					
No	Indikators	Σx	Σxi	%	Description
1	Feasibility	54	72	75	worth
2	Ease	54	72	75	worth
3	Safety	55	72	76	worth
4	Attractiveness	56	72	78	worth
Total		228	288	76	worth
Game Expert					
No	Indikators	Σx	Σxi	%	Description
1	Feasibility	55	72	76	worth
2	Ease	55	72	76	worth
3	Safety	56	72	78	worth
4	Attractiveness	56	72	78	worth
Total		218	288	77	worth
Overall Assessment Category				77	worth

Data Collection Technique

This research includes questionnaires, observation, documentation, and badminton long service ability tests. The questionnaires were given to media experts, material experts, teachers, as well as students taking General Physics courses, in accordance with the opinions of the teachers Sa'adah & Wahyu, (2022). Observations were made non-systematically without using observation instruments, while documentation was in the form of photographs during the

research. Badminton long service ability test was conducted based on the opinion of Singh & Mishra, (2020) by hitting 10 long service shots. Researchers also collected data through interviews and additional documentation.

Analysis Statistics

This study uses the research and development (R&D) method of the Borg and Gall model with 10 stages. The target games-based long service training model consists of 18 variations with different levels of difficulty. The requirements needed in variance analysis are data normality test and homogeneity test. As for further tests, the t-test was used using the Independent Sample Test. The analysis was assisted with the SPSS 22 application.

Results

The target games-based badminton long service training model for beginners was developed using the Borg & Gall model which consists of 10 stages, including needs analysis, planning, expert validation, small-scale test, revision, large-scale test, revision, effectiveness test, revision, and dissemination. Interviews with coaches and questionnaires to students at the Faculty of Sport Sciences, Medan State University revealed that coaches find it difficult to train long service due to the lack of variations in training models. As many as 85% of players agreed to be given additional training variations. Based on the results of the needs analysis, a three-stage training model was developed, (1) Easy category: 6 training models with shuttlecocks passing through a rope as high as 2.05 metres, (2) Medium category: 6 training models with a 2.30 metre high rope, (3) Difficult category: 6 training models with a 2.55 metre high rope.

Researchers developed an initial draft of a long service training model based on target games, involving one badminton expert coach and two expert lecturers. The validation results showed that 18 variations of the training model were declared feasible to be tested on a small scale, with an average feasibility percentage of 77%.

At the small group trial stage on FIK UNIMED students conducted on 12 novice players, the results showed a feasibility percentage of 75%, and the model was declared feasible to be tested to a large-scale group after minor revisions.

Table 4. Evaluation results and feedback from badminton experts

Easy Items	Medium Aitem	Difficult Items	Description
Model I Lefteasy Long Service (I LeLS)	Model I Leftmedium Long Service (I LmLS)	Model I Leftdifficult Long Service (I LdLS)	Can be implemented
Model I Rigteasy Long Service (I ReLS)	Model I Rightmedium Long Service (I RmLS)	Model I Rightdifficult Long Service (I RdLS)	
Model Leasy Long Service (LeLS)	Model Lmedium Long Service (LmLS)	Model Ldifficult Long Service (LdLS)	
Model Jeasy Long Service (JeLS)	Model Jmedium Long Service (JmLS)	Model Jdifficult Long Service (JdLS)	
Model Ueasy Long Service (UeLS)	Model Umedium Long Service (UmLS)	Model Udifficult Long Service (UdLS)	
Model Neasy Long Service (NeLS)	Model Nmedium Long Service (NmLS)	Model Ndifficult Long Service (NdLS)	

Table 5. Recapitulation of data from small group trial results

No	Indicator	Σx	Σxi	%	Description
1	Ease	678	864	78	worth
2	Attractiveness	647	864	75	worth
3	Usability	619	864	72	worth
4	Security	656	864	76	worth
Total		2600	3456	75	worth

Revisions to the results of the small-scale trial were made to improve the training model based on suggestions during the trial to better suit the research objectives. Furthermore, a large-scale group trial was conducted on 34 beginner players using 18 variations of the training model, and the results showed that the model could be applied well. After the large-scale test, minor revisions were made based on suggestions to increase the intensity and duration of training, but overall the model was declared feasible without major changes. The effectiveness test using a pre-experiment design with pretest-posttest showed that the long service training model based on target games was effective in improving the ability of novice players, as evidenced by the t-test on pretest and posttest data.

Table 6. Data recapitulation of large group trial results

No	Indicator	Σx	Σxi	%	Description
1	Ease	1925	2448	79	worth
2	Attractiveness	1890	2448	77	worth
3	Usability	1837	2448	75	worth
4	Security	1834	2448	79	worth
Total		7586	9792	77	worth

To measure the effectiveness of the model, a one group pretest-posttest pre-experiment was conducted on 42 novice players (experimental group) who used the new training model, and compared with 42 players in the control group who used the long service training model. Data from the pretest and posttest results were analysed using normality tests and t-tests.

The pretest and posttest data for both groups were tested using the Kolmogorov-Smirnov test to ensure normality, as well as the Levene test to test data homogeneity. The normality test results showed that the data were normally distributed with a significance value greater than 0.05. Meanwhile, the homogeneity test showed that the data of both groups were homogeneous with the following results:

Based on the Kolmogorov-Smirnov test results, the data from both groups were normally distributed with a significance value greater than 0.05. While the homogeneity test shows that the data from both groups are homogeneous, so it can be used in parametric statistical analysis. Results can be seen in table 8 and 9.

The Paired-Sample T-Test results for the experimental group showed a significant increase in badminton long service ability. The score difference between the pretest and posttest was -19.57, with a t value = -114.529 and Sig. (2-tailed) = 0.000. This indicates that the new training model

Table 7. Description of the analysis results of long service ability

Data Description	Experimental Group		Control Group	
	Pretest	Posttest	Pretest	Posttest
N	42	42	42	42
Mean	7.79	27.36	7.83	21.36
Standart Deviation	3.61	2.63	3.635	2.63
Variance	13.05	6.918	13.215	6.918
Skor Minimum	1.00	22.00	1.00	16.00
Skor Maksimum	15.00	33.00	16.00	27.00
Total Score	327	1149	329	897

Table 8. Long service ability data normality test results

No.	Variables	Kolmogorov-Smirnov			Description
		Statistics	df	Sig.	
1	Pretest Experimental Group	0.094	42	0.200*	Normal
	Posttest Experimental Group	0.102	42	0.200*	Normal
2	Pretest Control Group	0.122	42	0.125	Normal
	Posttest Control Group	0.102	42	0.200*	Normal

Table 9. Results of homogeneity test of long service ability data

Levene Statistic	df1	df2	Sig.
0.000	1	82	1.000

makes a positive contribution in improving long service skills. As for the control group, the difference in pretest and posttest scores was -13.52, with a t value = -77.470 and Sig. (2-tailed) = 0.000. Although there was an increase in ability, the results were not as great as the experimental group. Results can be seen in table 10 and 11.

Furthermore, the results of the Independent Samples T-Test showed that the target games-based long service training model was more effective than the old training model, with a t-value = 10.454, df = 82, and p-value <0.05. This indicates that there is a significant difference between the two groups. Results can be seen in table 12.

Then the effectiveness test was carried out on the target games-based badminton long service training model using the N-Gain test. After the effectiveness test, the long service training model based on target games was declared quite effective, with the results of the N-Gain test showing an average score of 0.61, which is included in the category quite effective in improving the long service skills of novice players. This final product is declared feasible without the need for further revision and is ready for dissemination. As a final step, this training model has been disseminated in the ICIESC international forum and published in the national journal Sports Science, so that it can be used more widely by coaches and beginner badminton players.

Table 10. Results of the paired-sample t test for the experimental group

		Paired Samples Test							
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95 % Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre test data long service kel eksprimen – Post test data long service kel eksprimen	-19.57143	1.10747	0.17089	-19.91654	-19.22632	-114.529	41	0.000

Table 11. Results of the paitred-sample t test for the control group

		Paired Samples Test							
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95 % Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre test data long service kel kontrol – Post test data long service kel kontrol	-13.52381	1.13133	0.17457	-13.87636	-13.17126	-77.470	41	0.000

Table 12. Differential test results of experimental group and control group

		Independent Samples Test								
		Levene's Test for Equality of Variances				t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95 % Confidence Interval of the Difference	
									Lower	Upper
Long service post test results	Equal variances assumed	0.000	1.000	10.454	82	0.000	6.0	0.57396	4.85820	7.14180
	Equal variances not assumed			10.454	82	0.000	6.0	0.57396	4.85820	7.14180

Discussion

This study aims to develop and test the effectiveness of a target games-based badminton long service training model for beginner players. In the context of sport, long service is an important technique that greatly affects the quality of badminton play. By improving players' long service ability, it is expected to contribute to their overall performance on the court. Through the development of this model, the researcher wants to provide a solution to the challenges faced by coaches in training long service, as well as providing more interesting and effective training variations.

The findings showed that the target games-based long service training model, when combined with players' motor skills, significantly improved the long service ability of beginner badminton players (Wacono & Janiarli, 2021). The second hypothesis states that players trained using a target games-based training model will show better long service skill improvement compared to players trained using

a conventional training model. This hypothesis is supported by the average long service skill score achieved by players in the experimental group. In line with the research results Ismik (2022) structured and varied training methods such as target games can contribute to the improvement of basic badminton skills, including long service.

The variety of exercises presented allows players to train in a more enjoyable and less monotonous way (Rossi et al., 2022). This is important to maintain player motivation and interest, especially for beginners who often experience boredom. In addition, the model is designed with varying levels of difficulty in mind, so coaches can tailor the exercises to each player's ability (Ichsan et al., 2023). As such, players can experience more significant development and feel more confident when playing.

In addition, the application of a long service training model based on target games has a positive influence on both players and coaches (Liang, 2022). For players, the use of this model not only improves their technical skills, but also

improves tactical understanding in the game. Players trained with this model will be better able to control the shuttlecock well and provide more strategic service. On the other hand, coaches also benefit from the development of this training model. With clear and structured guidelines, coaches can more easily design effective and efficient training sessions, as well as maximise training time (S. Ma et al., 2024).

It is hoped that this training method can be an effective tool to improve their skills. Players are expected to not only see it as a physical exercise, but also as an opportunity to learn and develop. By applying varied and fun exercises, players can enjoy the learning process and love badminton even more. This expectation aims to create a generation of players who are not only skilled, but also have a deep understanding of the game. Overall, this research makes a significant contribution in the world of badminton, particularly in the development of more innovative and effective training models. With proper implementation, this training model has the potential to improve the quality of training and overall performance of beginner badminton players.

Conclusions

This study successfully developed and evaluated the effectiveness of a target-game-based training model for improving badminton long serve skills in beginner players. Through a series of trials and refinements, the model demonstrated its ability to enhance long serve techniques in an engaging and varied manner. The findings revealed that the newly developed training approach significantly improved players' long serve abilities and proved more effective than traditional training methods. Additionally, novice players not only showed increased proficiency in executing long serves but also displayed greater motivation to practice. The structured design of the training model provides clear guidance for coaches, enabling them to tailor the intensity and difficulty levels according to the individual needs of players. This approach fosters a more effective and enjoyable learning environment. The study aspires for this training model to be widely adopted by coaches and players across different skill levels. Furthermore, it aims to serve as a foundation for future research exploring innovative badminton training techniques. By offering practical solutions for coaching, this research contributes to the cultivation of higher-quality badminton talent and encourages the continued advancement of training methodologies.

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Conflict of Interests

There is no conflict of interest.

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Розроблення цільової ігрової моделі тренування довгих подач у бадмінтоні для спортсменів-початківців

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Історія питання. Розвиток навичок виконання довгих подач у бадмінтоні є однією із важливих складових покращення ігрової результативності. Проблемаю підготовки гравців-початківців у бадмінтоні вважається низька різноманітність моделей тренування довгих подач, що впливає на рівень оволодіння цією технікою.

Мета дослідження. Мета дослідження полягала у розробленні та визначенні ефективності моделі тренування довгих подач на основі цільових ігор щодо поліпшення навичок виконання довгих подач бадмінтоністів-початківців.

Матеріали та методи. У рамках даної наукової праці застосовано методологію досліджень і розробок за моделлю Борга і Галла, що передбачає десять етапів, які включають в себе аналіз потреб і тестування ефективності. Суб'єктами дослідження були гравці-початківці, які навчалися на факультеті спортивних наук Меданського державного університету, вибірка складалася з 42 гравців, розподілених на експериментальну та контрольну групи. Для збору даних використовувався метод передекспериментального претест-посттестового дизайну. Аналіз даних проводився за допомогою програмного забезпечення SPSS із застосуванням t-критерію парних вибірок та t-критерію для незалежних вибірок.

Результати. Ґрунтуючись на результатах валідації, 18 варіацій моделей вправ було визнано доцільними для проведення широкомасштабних випробувань із середнім відсотком здійсненості 77 %. Такі показники отримано після внесення незначних змін на основі пропозицій щодо збільшення інтенсивності та тривалості вправ. Однак загалом визначено доцільність застосування зазначених моделей без суттєвих змін. Результати показали істотну різницю між групою, у якій застосовувалась цільова модель тренування на основі ігор, і групою з традиційною моделлю проведення тренувань ($p < 0,05$). Доведено ефективність застосування цільової моделі тренування на основі ігор щодо покращення вміння виконання довгих подач гравців-початківців.

Висновки. Згідно з результатами дослідження, можна стверджувати, що цільова модель тренування довгих подач на основі ігор забезпечує значну ефективність з точки зору вдосконалення навичок виконання довгих подач гравців-початківців. Доцільним також вважається ширше застосування зазначеної моделі у тренерській діяльності з підготовки бадмінтоністів-початківців.

Ключові слова: модель тренування, бадмінтон, довга подача, спортсмени-початківці, цільові ігри.

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Considering the Impact of Yoga on Psychological Well-being and Quality of Life in Perimenopausal Women: A Randomized Controlled Trial

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Abstract

Background. The onset of menopause and the perimenopausal period is often associated with the manifestation of psychological and physical symptoms that can adversely affect a woman's quality of life. Yoga has been identified as a promising non-pharmacological intervention for alleviating these symptoms.

Materials and methods. This randomized controlled trial assessed the effects of a 12-week Hatha Yoga intervention on psychological well-being and quality of life in 100 perimenopausal women (yoga group: n = 50; control group: n = 50). The participants in the yoga group engaged in Hatha Yoga practices, while the control group received no intervention. The psychological outcomes, including depression, anxiety, sleep quality, stress, climacteric symptoms, and self-esteem, were measured using standardized scales before and after the intervention. Hormonal analysis and anthropometric measures were also collected.

Results. The yoga group demonstrated significant improvements in all psychological parameters compared to the control group. Depression and anxiety scores reduced by 6.3 points ($p = 0.001$, $d = 0.78$) and 6.8 points ($p < 0.001$, $d = 0.82$), respectively, while perceived stress, sleep quality, climacteric symptoms, and self-esteem improved significantly ($p < 0.01$). The study also revealed a substantial increase in quality of life in the yoga group ($p < 0.001$, $d = 0.86$), along with a reduction in neuroticism scores ($p < 0.001$, $d = 0.79$). In contrast, the control group exhibited minimal changes across all measures.

Conclusions. These findings highlight yoga's effectiveness in alleviating psychological distress and enhancing quality of life among perimenopausal women. Yoga serves as an accessible and holistic approach to managing menopausal symptoms and promoting mental well-being. It is recommended that further research should focus on investigating the potential long-term benefits and physiological mechanisms underlying these positive alterations.

Keywords: anxiety, climacteric symptoms, depression, perimenopausal, self-esteem, sleep quality.

Introduction

Menopause marks the cessation of menstruation and the end of a woman's reproductive years, typically occurring between the ages of 45 and 55 (Davis et al., 2015). However, the transition to menopause, known as perimenopause, often begins several years before the last menstrual period and is characterized by fluctuating levels of estrogen and progesterone (Hale & Burger, 2009). These hormonal fluctuations can lead to a variety of symptoms such as hot flashes, night sweats, mood swings, irritability, depression, anxiety, sleep disturbances, and reduced quality of life (Woods et al., 2021). These symptoms can severely impact the psychological well-being and overall health of women during this stage (Ambikairajah et al., 2022).

The conventional management of perimenopausal symptoms often includes pharmacological interventions like hormone replacement therapy (HRT) and antidepressants (Jeong & Park, 2022). While these treatments are effective in managing some symptoms, they are associated with potential side effects such as weight gain, increased risk of cardiovascular events, and breast cancer, especially with long-term use (Gatenby & Simpson, 2024). This has prompted the exploration of alternative and complementary therapies that offer fewer side effects and more holistic benefits (Ninot, 2021).

One promising non-pharmacological intervention is yoga, a mind-body practice that combines physical postures, controlled breathing, and meditation techniques (Wankhar et al., 2024). Yoga has gained increasing recognition for its role in improving mental health and physical well-being (Ghosh et al., 2024; K.S. et al., 2023). Previous studies have suggested that yoga can alleviate symptoms such as anxiety, depression, and sleep disturbances, all of which are commonly experienced by perimenopausal women (Padmavathi et al., 2023). For instance, a systematic review and meta-analysis of randomized controlled trials (RCTs) conducted by Gangadharan et al. (2024) found that yoga significantly reduced menopausal symptoms and improved overall quality of life in menopausal women (Gangadharan et al., 2024). Similarly, a study by Nayak et al. (2014) demonstrated that yoga therapy had significant effects on psychological health, vasomotor symptoms, and overall quality of life, especially for women in the perimenopausal phase (Nayak et al., 2014). Moreover, a study by Khadka et al. (2022) found that yoga practice significantly increased serum levels of estrogen and progesterone in perimenopausal women, suggesting that yoga may have beneficial effects on hormonal balance during the transition to menopause (Khadka et al., 2022). In a recent study by Susanti et al. (2022), yoga was shown to improve sleep quality and reduce menopausal symptoms in postmenopausal and perimenopausal women, further supporting the efficacy of yoga in addressing the psychological and physical challenges of menopause (Susanti et al., 2022).

Despite these promising findings, there is a lack of comprehensive studies specifically focusing on the effects of Hatha Yoga on both the psychological and physiological parameters in perimenopausal women. This gap in the literature highlights the need for further investigation into how yoga can impact various aspects of perimenopausal health, including hormonal regulation, psychological well-being, and overall quality of life.

Materials and Methods

Study Design

This study employed a parallel-group randomized controlled trial design conducted over 12 weeks. Participants attended sessions five days per week (Monday through Friday), with each session lasting 75 minutes. The study included an experimental group that received a yoga intervention and a control group that did not receive any intervention.

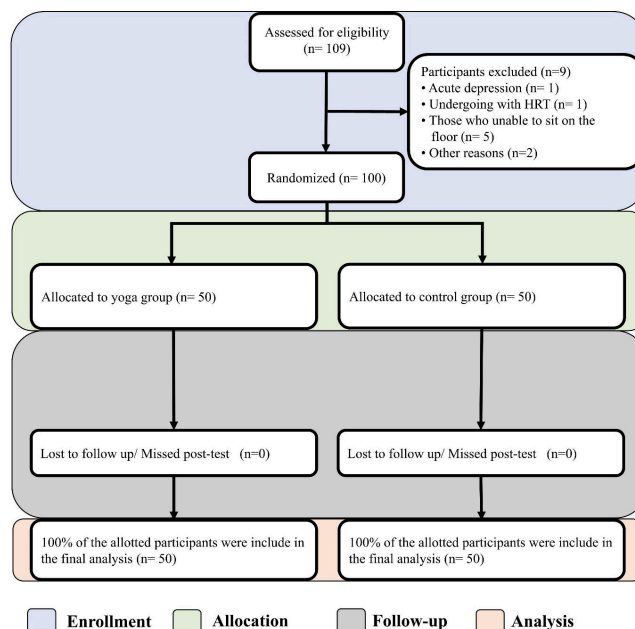


Fig 1. Semantic repetition of the research study

Participants

The study targeted perimenopausal women aged 40–55 years residing in Thane City, India. Participants were required to be from urban areas and to have follicle-stimulating hormone (FSH) levels of 15 or higher on the sixth day of their menstrual cycle. Women with acute depression ($n = 1$), those undergoing hormone replacement therapy (HRT) ($n = 1$), individuals unable to sit on the floor ($n = 5$), and those with severe backache, osteoarthritis, hypertension, diabetes mellitus, or surgical menopause ($n = 2$) were excluded. Semantic representation and sample sizes in various stages of research were presented in Figure 1.

Sample Size and Randomization

A statistical calculation with a 95% confidence level and 80% power determined the total sample size to be 100 participants, with 50 allocated to the experimental group and 50 to the control group. Participants were selected through simple random sampling from a pool of eligible women visiting a renowned gynecologist in Thane City.

Ethical Considerations

The study was approved (MMCH&RI IEC/PhD/20/JAN/23) by the Institutional Ethics Committee of Meenakshi

Table 1. Yoga practices for 12 weeks

Component	Practice	Duration (Minutes)	Purpose
Warm-Up	Joint rotations, gentle stretches		Prepare the body, improve flexibility, and prevent injury.
Asanas	Tadasana (Mountain Pose)	10	Improve posture and balance.
	Trikonasana (Triangle Pose)		Stretch and strengthen muscles, enhance hormonal balance.
	Bhujangasana (Cobra Pose)		Stimulate adrenal glands and improve spinal flexibility.
	Baddha Konasana (Bound Angle Pose)		Enhance pelvic health and hormonal function.
	Shavasana (Corpse Pose)		Induce deep relaxation and reduce fatigue.
Pranayama	Nadi Shodhana (Alternate Nostril)	25	Balance energy and calm the mind.
	Bhramari (Bee Breathing)		Reduce anxiety and improve concentration.
Meditation	Mindfulness meditation	15	Promote emotional stability and reduce stress.
Relaxation	Yoga Nidra (Guided Relaxation)	10	Foster mental calmness and improve sleep quality.

Academy of Higher Education and Research. Detailed informed consent forms were provided to participants in both English and Marathi to ensure clear understanding of the study's purpose, procedures, risks, and benefits. Participant confidentiality was maintained throughout the study, and all ethical guidelines were strictly adhered to.

Intervention

The intervention consisted of a structured 12-week yoga program specifically designed to address the hormonal and psychological challenges faced by perimenopausal women. Participants in the experimental group attended yoga sessions five days a week, with each session lasting 75 minutes. The yoga practice incorporated a combination of asanas (postures), pranayama (breathing techniques), dhyana (meditation), and relaxation techniques, focusing on improving physical and mental well-being. The sessions were led by certified yoga instructors and adapted to suit the needs of perimenopausal women. Warm-up exercises were followed by a sequence of postures to enhance flexibility, hormonal balance, and strength, breathing exercises to promote relaxation and improve lung capacity, and meditation to reduce stress and anxiety. Each session concluded with guided relaxation to foster mindfulness and calmness.

Outcome Measures - Psychological Parameters

Hamilton Depression Rating Scale (HDRS): The Hamilton Depression Rating Scale (HDRS) is a 17-item clinician-administered assessment tool measuring depression severity. Each item is rated on either a 5-point scale (0-4) or a 3-point scale (0-2), with a total score range of 0-52. Scores of 0-7 indicate normal mood, 8-13 suggest mild depression, 14-18 indicate moderate depression, 19-22 show severe depression, and scores ≥ 23 represent very severe depression. The scale evaluates key symptoms including mood, guilt, suicide ideation, insomnia, work/activities, psychomotor retardation/agitation, anxiety, and somatic symptoms (Hieronymus et al., 2021).

Pittsburgh Sleep Index (PSQI): The Pittsburgh Sleep Index comprises 19 self-rated questions and 5 questions rated

by a bed partner or roommate (if available). These questions are combined to form 7 component scores: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. Each component score ranges from 0-3. The sum of these 7 component scores yields a global PSQI score ranging from 0-21. A global score >5 indicates poor sleep quality, with higher scores representing progressively worse sleep quality (Zitser et al., 2022).

Greene Climacteric Scale: The Greene Climacteric Scale consists of 21 items measuring various menopausal symptoms across four domains: psychological (11 items), somatic/physical (7 items), vasomotor (2 items), and sexual (1 item). Each symptom is rated on a 4-point scale from 0 (not at all) to 3 (extremely). The psychological domain is further divided into anxiety (items 1-6) and depression (items 7-11) subscales. Total scores range from 0-63, with higher scores indicating more severe symptoms. Domain scores can be calculated separately: psychological (0-33), somatic (0-21), vasomotor (0-6), and sexual (0-3) (Greene, 2008).

Perceived Stress Scale (PSS): The Perceived Stress Scale is a 10-item instrument measuring the degree to which situations in one's life are appraised as stressful. Items are rated on a 5-point Likert scale from 0 (never) to 4 (very often). Four items (4, 5, 7, and 8) are positively stated and must be reverse scored. Total scores range from 0-40, with scores of 0-13 indicating low stress, 14-26 suggesting moderate stress, and 27-40 representing high perceived stress levels (Chan & La Greca, 2020).

WHO Quality of Life Questionnaire (WHOQOL-BREF): The WHOQOL-BREF contains 26 items, with 24 items across four domains: physical health (7 items), psychological health (6 items), social relationships (3 items), and environment (8 items), plus 2 individual items assessing overall quality of life and general health. Each item is rated on a 5-point Likert scale from 1-5. Domain scores are scaled in a positive direction (higher scores indicate better quality of life) and are transformed to a 0-100 scale. Three items (3, 4, and 26) must be reverse scored before calculating domain scores (Krägeloh et al., 2011).

Rosenberg's Self Esteem Scale (RSES): The Rosenberg Self-Esteem Scale is a 10-item scale measuring global self-worth.

Items are answered on a 4-point Likert scale from strongly disagree (0) to strongly agree (3). Five items (2, 5, 6, 8, 9) are negatively worded and must be reverse scored. Total scores range from 0-30, with scores below 15 suggesting low self-esteem, 15-25 indicating normal self-esteem, and scores above 25 representing high self-esteem (Martín-Albo et al., 2007).

NEO's Big Five Inventory (BFI): The NEO's Big Five Inventory consists of 44 items measuring five personality dimensions: Extraversion (8 items), Agreeableness (9 items), Conscientiousness (9 items), Neuroticism (8 items), and Openness (10 items). Items are rated on a 5-point scale from 1 (disagree strongly) to 5 (agree strongly). Sixteen items are reverse scored. Each personality dimension is scored separately, with higher scores indicating stronger presence of that trait. Raw scores are converted to T-scores (mean = 50, SD = 10) for interpretation against population norms (Fossati et al., 2011).

Data Collection

Psychological assessments were conducted before and after the 12-week intervention period. Participants completed all questionnaires under supervision to ensure proper understanding and accurate responses. The research team maintained standardized testing conditions for all assessments to minimize variability.

Statistical Analysis

Data analysis was conducted using paired t-tests to evaluate within-group changes and independent t-tests for between-group comparisons of psychological parameters before and after the intervention. The mean differences (MD) were calculated to quantify the magnitude of changes for each parameter. Effect sizes (Cohen's *d*) were also computed to assess the practical significance of the observed differences, with thresholds of 0.2, 0.5, and 0.8 indicating small, medium, and large effects, respectively (Kumar et al., 2024). A significance level of 0.05 was set to determine statistical significance for all tests. Statistical analyses were performed using IBM SPSS Statistics software (version 25). Results are presented as mean $\pm$ standard deviation, along with mean differences and effect sizes to provide a comprehensive understanding of the intervention's impact.

Results

Baseline Characteristics

The baseline characteristics of the study participants in the yoga and control groups were comparable, with no statistically significant differences observed across demographic, anthropometric, or clinical parameters (Table 2). The mean age of participants was 46.5 ± 4.2 years in the yoga group and 47.1 ± 3.9 years in the control group ($p = 0.56$). Other variables, including BMI, symptom duration, blood pressure, resting heart rate, and menstrual cycle length, were also similar between groups ($p > 0.05$), indicating homogeneity in baseline profiles.

Changes in Psychological Variables

Significant improvements in psychological and quality-of-life parameters were observed in the yoga group

compared to the control group following the intervention (Table 3). Depression scores (Hamilton Depression Rating Scale) in the yoga group decreased by 6.3 points ($p = 0.001$, $d = 0.78$), while the control group showed minimal change. Anxiety scores (Hamilton Anxiety Rating Scale) were reduced by 6.8 points in the yoga group ($p < 0.001$, $d = 0.82$), with negligible change in the control group. The yoga group also demonstrated marked improvements in sleep quality (Pittsburgh Sleep Index, -5.4 - 5 ; $p < 0.01$, $d = 0.76$), climacteric symptoms (Greene Climacteric Scale, -9.4 ; $p < 0.001$, $d = 0.84$), and perceived stress (Perceived Stress Scale, -7.2 ; $p = 0.001$, $d = 0.75$). Notable gains were observed in self-esteem (Rosenberg's Self-Esteem Scale, $+5.6$; $p < 0.001$, $d = 0.77$) and quality of life (WHO Quality of Life Scale, $+14.4$; $p < 0.001$, $d = 0.86$), along with reduced neuroticism scores on the NEO Big Five Scale -9.6 ; $p < 0.001$, $d = 0.79$). Figures 2 and 3 provide the graphical representations of the effect size, mean, and standard deviation on outcome measures (psychological parameters).

Table 2. Baseline characteristics of perimenopausal women

Parameters	Yoga Group (n = 50)	Control Group (n = 50)	p-value
Age (years)	46.5 ± 4.2	47.1 ± 3.9	0.56
Height (cm)	158.3 ± 5.6	157.8 ± 5.9	0.73
Weight (kg)	65.4 ± 8.3	64.9 ± 7.8	0.81
BMI (kg/m ²)	26.1 ± 3.2	26.3 ± 3.4	0.82
Duration of symptoms (months)	18.5 ± 7.4	17.9 ± 8.1	0.77
Menstrual cycle length (days)	35.2 ± 6.8	34.8 ± 7.2	0.83
Systolic BP (mmHg)	126.5 ± 8.4	125.8 ± 9.1	0.75
Diastolic BP (mmHg)	82.3 ± 6.2	81.9 ± 6.5	0.8
Resting heart rate (bpm)	74.6 ± 5.8	75.2 ± 6.1	0.69

The control group showed negligible changes in all measured parameters, highlighting the efficacy of yoga therapy in improving psychological well-being and quality of life in perimenopausal women.

Discussion

The findings from this study provide compelling evidence of the significant psychological and physiological benefits of yoga therapy for perimenopausal women. Participants in the yoga group demonstrated substantial improvements across various psychological measures, including reductions in depression, anxiety, perceived stress, and climacteric symptoms. These improvements were accompanied by enhancements in sleep quality, self-esteem, and overall quality of life, all of which were statistically significant with moderate-to-large effect sizes. These results highlight the clinical relevance of yoga as a non-pharmacological intervention for alleviating the mental and emotional burdens commonly associated with the perimenopausal phase.

The observed reductions in depression and anxiety, as measured by the Hamilton scales, underscore yoga's potential

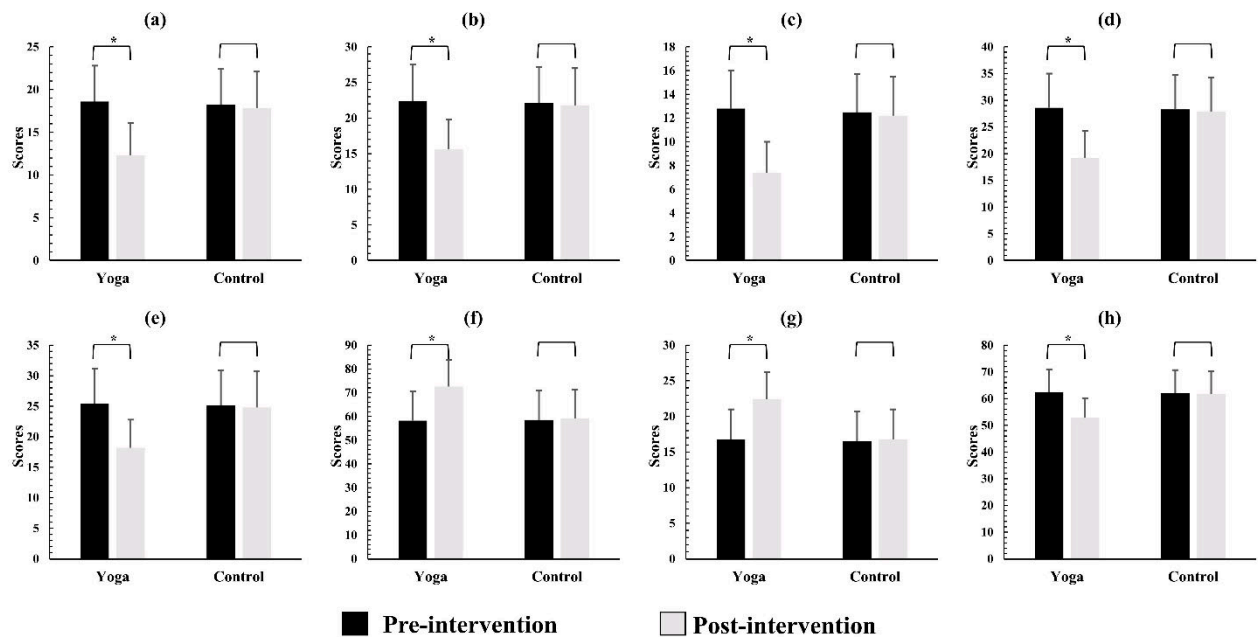


Fig 2. Graphical representation of means and SD on psychological parameters: (a) Hamilton Depression Rating Scale, (b) Hamilton Anxiety Rating Scale, (c) Pittsburgh Sleep Index, (e) Greene Climacteric Scale, (f) WHO Quality of Life, (g) Rosenberg's Self Esteem Scale, (h) NEO's Big Five (Neuroticism)

Table 3. Changes in the psychological variables before and after intervention

Outcome Measure	Group	Pre-intervention Mean (SD)	Post-intervention Mean (SD)	Mean Difference	t-value	p-value	Effect Size (Cohen's d)
Hamilton Depression Rating Scale	Yoga (n=50)	18.6 (4.2)	12.3 (3.8)	-6.3	4.82	0.001*	0.78
	Control (n=50)	18.2 (4.1)	17.8 (4.3)	-0.4	0.23	0.84	0.10
Hamilton Anxiety Rating Scale	Yoga (n=50)	22.4 (5.1)	15.6 (4.2)	-6.8	5.14	<0.001*	0.82
	Control (n=50)	22.1 (5.0)	21.8 (5.2)	-0.3	0.19	0.86	0.06
Pittsburgh Sleep Index	Yoga (n=50)	12.8 (3.2)	7.4 (2.6)	-5.4	4.96	<0.001*	0.76
	Control (n=50)	12.5 (3.1)	12.2 (3.3)	-0.3	0.21	0.83	0.09
Greene Climacteric Scale	Yoga (n=50)	28.6 (6.4)	19.2 (5.1)	-9.4	5.32	<0.001*	0.84
	Control (n=50)	28.3 (6.2)	27.9 (6.3)	-0.4	0.28	0.81	0.05
Perceived Stress Scale	Yoga (n=50)	25.4 (5.8)	18.2 (4.6)	-7.2	4.78	0.001*	0.75
	Control (n=50)	25.1 (5.7)	24.8 (5.9)	-0.3	0.20	0.85	0.05
WHO Quality of Life (Overall)	Yoga (n=50)	58.2 (12.4)	72.6 (11.2)	14.4	5.46	<0.001*	0.86
	Control (n=50)	58.5 (12.2)	59.1 (12.3)	0.6	0.28	0.81	0.05
Rosenberg's Self Esteem Scale	Yoga (n=50)	16.8 (4.2)	22.4 (3.8)	5.6	4.92	<0.001*	0.77
	Control (n=50)	16.5 (4.1)	16.8 (4.2)	0.3	0.22	0.84	0.07
NEO's Big Five (Neuroticism)	Yoga (n=50)	62.4 (8.6)	52.8 (7.4)	-9.6	4.88	<0.001*	0.79
	Control (n=50)	62.1 (8.4)	61.8 (8.5)	-0.3	0.18	0.87	0.04

in regulating mood and mitigating emotional distress during this life stage. Similarly, improvements in sleep quality, as measured by the Pittsburgh Sleep Quality Index, and self-esteem, assessed via the Rosenberg Self-Esteem Scale, suggest that yoga not only fosters a sense of well-being but also supports better sleep patterns, which are often disrupted during the menopausal transition. The significant reduction

in neuroticism scores further emphasizes yoga's role in enhancing emotional resilience during perimenopause.

In contrast, the control group showed negligible changes across all measured variables, reinforcing the notion that the positive effects observed in the yoga group were specific to the structured mind-body practice. This outcome aligns with previous research, which suggests that the multifaceted

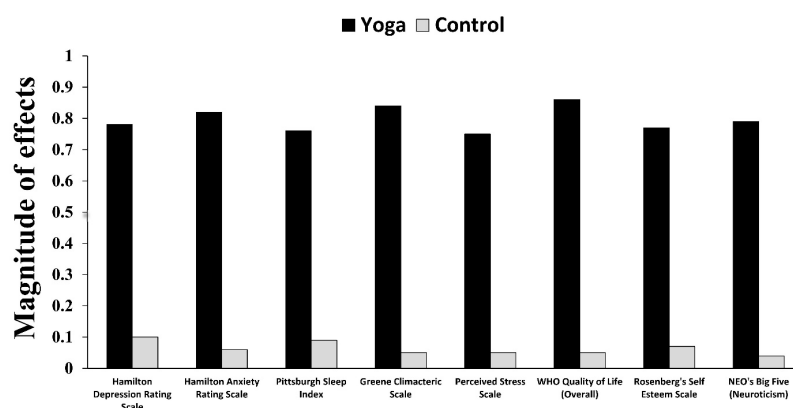


Fig 3. Magnitude of effect (Cohen's d) of pre to post-intervention on Psychological Parameters

nature of yoga—including physical postures, breathing exercises, meditation, and relaxation techniques—acts synergistically to regulate hormonal imbalances, improve autonomic nervous system functioning, and promote emotional well-being. The physiological changes observed in this study, such as reductions in stress and menopausal symptoms, support the idea that yoga may play a crucial role in managing the hormonal fluctuations and emotional challenges associated with perimenopause.

Further supporting the efficacy of yoga during menopause, a study by Nayak et al. (2014) found that a 12-week yoga program significantly improved physical, psychological, vasomotor, and sexual symptoms in perimenopausal women. In that study, yoga participants exhibited superior improvements in overall quality of life compared to those in an exercise group. The findings indicate that yoga is not only a safe and cost-effective intervention for managing menopausal symptoms but also provides a holistic approach to enhancing women's well-being during this transitional period (Nayak et al., 2014).

A study by Khadka et al. (2022) further examined the hormonal impact of yoga, revealing that yoga practice led to significant increases in serum estrogen and progesterone levels in perimenopausal women, suggesting that yoga may have a beneficial effect on hormonal regulation. Conversely, no significant changes in luteinizing hormone (LH) and follicle-stimulating hormone (FSH) levels were observed. These results suggest that yoga may help mitigate some of the hormonal fluctuations associated with menopause, particularly those that contribute to symptoms such as hot flashes, mood swings, and sleep disturbances (Khadka et al., 2022).

Additional evidence supporting the role of yoga in managing menopausal symptoms is provided by a randomized controlled trial by Susanti et al. (2022), which found that yoga significantly reduced menopausal symptoms and improved sleep quality in postmenopausal and perimenopausal women, with the most notable effects observed in the postmenopausal group. After 20 weeks of yoga practice, participants experienced improvements in sleep quality and menopausal symptoms, even after controlling for social support, depression, anxiety, and stress. Interestingly, no such improvements were noted in premenopausal women, highlighting the particular

relevance of yoga for women in the later stages of menopause (Pratima G. Suryawanshi et al., 2023).

Furthermore, the results of a study by Jorge et al. (2016) investigating Hatha Yoga in postmenopausal women found similar benefits, with yoga participants showing significant reductions in menopausal symptoms, stress, and depression, as well as improved quality of life when compared to control and exercise groups. Hormonal analysis revealed decreased levels of FSH and LH in the yoga and exercise groups, further suggesting that yoga may help balance hormonal fluctuations during menopause (Jorge et al., 2016).

In a broader systematic review of yoga interventions for menopausal women, Gangadharan et al. (2024) synthesized the findings from 10 randomized controlled trials involving 1463 participants. The review confirmed that yoga is a safe and effective intervention for managing menopausal symptoms, offering improvements in mood, sleep, and overall quality of life without significant adverse effects. The evidence supports the integration of yoga into clinical practice as a non-pharmacological strategy for enhancing the well-being of menopausal women (Gangadharan et al., 2024).

Collectively, these studies provide strong evidence that yoga is an effective, safe, and accessible intervention for managing both the psychological and physiological challenges of menopause. The evidence suggests that regular yoga practice can alleviate symptoms such as depression, anxiety, and stress, improve sleep quality, and enhance overall quality of life. Given its wide-ranging benefits, yoga presents a promising complementary therapy for menopausal women and should be considered an essential part of any holistic approach to managing this life stage. Healthcare providers are encouraged to incorporate yoga into care plans for menopausal women to optimize their physical and emotional well-being during this transitional phase.

Limitations

Despite its strengths, the study has several limitations. First, it relied on self-reported questionnaires for psychological assessments, which may introduce response bias. Second, the generalizability of the findings may be limited as participants were drawn from a single urban area.

Third, the lack of a placebo or active control group means that the observed benefits cannot be definitively attributed solely to the yoga intervention. Future studies could address these limitations by including larger, more diverse samples and incorporating objective measures of physiological and hormonal changes.

Conclusions

This study demonstrates that a 12-week structured yoga intervention is an effective non-pharmacological approach for improving psychological well-being and quality of life in perimenopausal women. The significant reductions in depression, anxiety, stress, and climacteric symptoms, coupled with enhanced sleep quality and self-esteem, suggest yoga's potential as a holistic therapy to address the multifactorial challenges of perimenopause.

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Conflict of Interest

The authors declare no conflict of interest.

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Розгляд впливу йоги на стан психологічного благополуччя та якість життя жінок у період перименопаузи: Рандомізоване контрольоване дослідження

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Історія питання. Початок менопаузи та перименопаузального періоду часто пов'язаний із проявом психологічних і фізичних симптомів, що можуть негативно вплинути на якість життя жінки. Йога визначається як перспективний нефармакологічний спосіб полегшення зазначених симптомів.

Матеріали та методи. В рамках цього рандомізованого контрольованого дослідження оцінювався вплив 12-тижневих занять хатха-йогою на стан психологічного благополуччя та якість життя 100 жінок у період перименопаузи (група занять йогою: n = 50; контрольна група: n = 50). Учасниці досліджуваної групи займалися практикою хатха-йоги, тоді як контрольна група не залучалася до жодних інтервенцій. Психологічні показники, включаючи депресію, тривогу, якість сну, стрес, клімактеричні симптоми та рівень самооцінки, вимірювалися за допомогою стандартизованих шкал на етапах перед початком та після завершення інтервенції. Крім того, проведено збір даних гормонального аналізу та антропометричних вимірювань.

Результати. Група, що займалась йогою, продемонструвала значні покращення за всіма психологічними параметрами порівняно із контрольною групою. Показники депресії та тривоги знизилися на 6,3 бала (p = 0,001, d = 0,78) та 6,8 бала (p < 0,001, d = 0,82) відповідно, тоді як сприйняття стресу, якість сну, клімактеричні симптоми та самооцінка суттєво поліпшилися (p < 0,01). Також дослідження виявило значне підвищення якості життя в групі занять йогою (p < 0,001, d = 0,86), а також зниження показників невротизму (p < 0,001, d = 0,79). Натомість у контрольній групі спостерігалися мінімальні зміни за всіма показниками.

Висновки. Отримані дані підкреслюють ефективність застосування йоги з метою полегшення психологічного дистресу та покращення якості життя серед жінок у період перименопаузи. Йога виступає в якості доступного і цілісного підходу до подолання менопаузальних симптомів і сприяння психічному благополуччю. Подальші дослідження рекомендують зосередити на вивченні потенційних довгострокових переваг та фізіологічних механізмів, що лежать в основі вказаних позитивних змін.

Ключові слова: тривога, клімактеричні симптоми, депресія, перименопаузальний, самооцінка, якість сну.

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Validating the Physical Educators' Attitude Toward Teaching Individuals with Disabilities III (PEATID III) Instrument for Physical Education Teachers: Supporting Inclusive Education in Indonesia

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Abstract

Objectives. This study aimed to validate the Physical Educators' Attitude Toward Teaching Individuals with Disabilities III (PEATID III) instrument in the context of physical education in Indonesia, especially in Pekanbaru City.

Materials and methods. This study involved 120 physical education teachers in Pekanbaru City who were selected by purposive sampling. Inclusion criteria for respondents included teachers who had experience teaching students with disabilities in regular classes and were willing to participate in this study. To examine Physical Educators' Attitudes Toward Teaching Individuals with Disabilities III (PEATID III) in the context of physical education, this instrument consists of 12 statements that measure three aspects of teacher attitudes, namely: (i) outcomes of teaching students with disabilities, (ii) impact on student learning, and (iii) need for additional training.

Results. All items' Content Validity Ratio (CVR) values were over 0.60, indicating high relevance to Indonesian social and cultural environment. Construct validity was tested using confirmatory factor analysis (CFA) and found a satisfactory model fit ($\chi^2/df = 2.31$; CFI = 0.93; RMSEA = 0.06). The instrument's Cronbach's alpha coefficient was 0.88, indicating strong internal consistency. Descriptive analysis showed that physical education teachers' attitudes towards teaching students with disabilities tended to be positive ($M = 3.87$; $SD = 0.64$). Teachers with more than five years of experience and additional training had more inclusive attitudes.

Conclusions. This study makes a significant contribution in providing a reliable instrument to evaluate teachers' attitudes towards inclusive education, supporting the development of policies and training programs relevant to local needs. The findings also provide a basis for further research that focuses on strengthening inclusive education in Indonesia through a more comprehensive and representative approach.

Keywords: validation, PEATID III, physical education, inclusive education.

Introduction

Inclusive physical education has become a crucial component in creating an equal and supportive learning environment for all students, including those with disabilities (Nurul et al., 2024; Zhang, 2024). The principle of inclusion demands collaboration between policy, infrastructure, and

educator readiness (Donaire, 2024). Physical education teachers play a strategic role in creating meaningful learning experiences for students with diverse abilities (Al Yaqoubi, 2024). However, challenges such as a lack of training, unprepared facilities, and negative attitudes toward students with disabilities are often significant barriers to the implementation of inclusive physical education (Greguol et al., 2018; Rekaa et al., 2019). Teachers also often feel unprepared and lack confidence in their ability to effectively include students with disabilities (Greguol et al., 2018; McGrath et al., 2019).

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Teachers' attitudes toward teaching students with disabilities are one of the factors that influence the success of inclusive education (Bandyopadhyay & Dhara, 2021; Van Steen & Wilson, 2020). However, attitudes can vary based on factors such as gender, age, training, and experience with students with disabilities (Amka, 2020; Vaz et al., 2015). Teacher self-efficacy, perceived school support, and religious beliefs also play a role in shaping attitudes (Amka, 2020; Vaz et al., 2015). Training in inclusive education has been shown to positively influence teacher attitudes (Lika, 2016). The type and severity of disability can affect teachers' attitudes, with some disabilities being viewed more favorably than others (Bandyopadhyay & Dhara, 2021). Researchers emphasize the importance of providing teachers with ongoing support and resources to promote positive attitudes toward inclusive education (González-Rojas & Triana-Fierro, 2018).

Positive attitudes can encourage the implementation of adaptive and participatory learning strategies (Bertills & Björk, 2024), while negative attitudes can be a barrier for students to have an optimal learning experience (Yolak et al., 2020). Therefore, measuring teachers' attitudes is an important step to understand and improve their readiness to face these challenges. One widely used instrument in measuring physical education teachers' attitudes towards teaching students with disabilities is the Physical Educators' Attitude Toward Teaching Individuals with Disabilities III (PEATID III) (Casebolt & Rizzo, 2004). This instrument has been widely used by researchers in various countries (Antala et al., 2022; Reina et al., 2021). The use of PEATID III helps in identifying attitudinal aspects that need to be improved through training and professional development. In addition, the measurement results can be used to design more effective interventions in creating an inclusive and supportive learning environment.

The PEATID III instrument developed by Rizzo (1993) is a measurement tool based on the Theory of Reasoned Action (Al-Suqri & Al-Kharusi, 2015). This theory emphasizes that attitudes and subjective norms can predict behavioral intentions, which in turn influence actions. In the context of physical education, PEATID III measures three main aspects: (i) the outcomes of teaching students with disabilities in regular classes, (ii) the impact on overall student learning, and (iii) the need for further academic preparation to teach students with disabilities (Folsom-Meek & Rizzo, 2002). The validity and reliability of this instrument have been tested in various countries, showing that PEATID III is a reliable measurement tool to assess teacher attitudes (Antala et al., 2022; Reina et al., 2021). The use of PEATID III also enables comprehensive data collection for cross-cultural analyses to understand teacher attitudes across various educational contexts. In addition, the resulting findings can serve as a basis for designing training policies that better suit the needs of teachers in each country.

However, to date, no research has validated the PEATID III instrument in Indonesia, especially in the context of physical education. In fact, Indonesia has a diverse cultural, social and educational system that influences teachers' perceptions and attitudes towards students with disabilities. Validating this instrument in Indonesia is important to ensure its relevance and reliability in the local context. Thus, the results of the study can serve as a basis for developing more effective inclusive education training and policies. In addition, local validation allows for a more accurate mea-

surement of the influence of cultural factors on teachers' attitudes, as revealed in studies in various countries (Antala et al., 2022; Reina et al., 2021). Validation studies in Indonesia can make a significant contribution to enriching the literature on the adaptation of teacher attitude instruments to disability in developing countries (Rofiah, 2022).

This study focused on validating the PEATID III instrument for physical education teachers in Pekanbaru City. This city was chosen because it reflects the dynamics of inclusive education in urban Indonesia. The validation included testing component structure, internal reliability, and cultural relevance so that the results could provide a comprehensive picture of teachers' readiness to implement inclusive physical education. The main objective of this study was to test the validity and reliability of PEATID III in Indonesia. In addition, this study also aimed to identify factors that influence teachers' attitudes toward teaching students with disabilities. By understanding these attitudes, it is hoped that appropriate interventions can be designed to improve teachers' competence and confidence in implementing inclusive physical education.

The results of this study are expected to contribute significantly to the development of policies and teacher training programs in Indonesia. In addition, the validation of this instrument can also serve as a foundation for future studies that explore more deeply the relationship between teacher attitudes, education policy, and the implementation of inclusive physical education. Through this, inclusive education in Indonesia can progress further, providing equal opportunities for all students to develop and reach their full potential.

Materials and methods

Participants

This study involved 120 physical education teachers in Pekanbaru City who were selected by purposive sampling. Inclusion criteria for respondents included teachers who had experience teaching students with disabilities in regular classes and were willing to participate in this study. Participation was done voluntarily by signing the consent form after receiving an explanation regarding the purpose and procedures of the study. The composition of respondents included 65% male and 35% female with an age range of 25 to 55 years (Table 1).

Instrument

The main instrument used in this study was "Physical Educators' Attitude Toward Teaching Individuals with Disabilities III" (PEATID III), adapted from Rizzo (1993). This instrument consists of 12 statements that measure three aspects of teacher attitudes, namely: (i) outcomes of teaching students with disabilities, (ii) impact on student learning, and (iii) need for additional training. Each statement was rated using a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree). In addition, adaptations were made to the language and context to ensure cultural relevance.

Procedures

The steps of this study began with the preparation stage, where the researcher adapted the Physical Educators'

Table 1. Characteristics of research participants by school level and gender

School Level	Number of Teacher	Gender	Age (M ± SD)	Experience teaching students with disabilities
Primary School	40 (33.3%)	26 M, 14 F	38.5 ± 7.8	> 5 years: 21 (52.5%), < 5 years: 19 (47.5%)
Junior High School	40 (33.3%)	26 M, 14 F	39.0 ± 8.5	> 5 years: 21 (52.5%), < 5 years: 19 (47.5%)
High School	40 (33.3%)	26 M, 14 F	38.7 ± 8.3	> 5 years: 22 (55%), < 5 years: 18 (45%)
Total	120 (100%)	78 M, 42 F	38.7 ± 8.2	> 5 years: 64 (53%), < 5 years: 56 (47%)

Table 2. Content validity of PEATID III instrument

No. Item	Description Item (English – Indonesia)	Value CVR	Conclusion
Teaching Outcomes of Students with Disabilities			
1	Students with disabilities will not be accepted by classmates without disabilities (Siswa dengan disabilitas tidak akan diterima oleh teman sekelas tanpa disabilitas).	0.78	The items are relevant and appropriate.
2	The presence of students with disabilities will disrupt the harmony of the classroom (Kehadiran siswa dengan disabilitas akan mengganggu harmoni kelas).	0.82	The items are relevant and appropriate.
3	Teaching students with disabilities in regular classes places an unfair additional burden on teachers (Mengajar siswa dengan disabilitas di kelas reguler memberikan beban tambahan yang tidak adil pada guru).	0.75	The items are relevant and appropriate.
4	Teaching students with disabilities means increasing my workload (Mengajar siswa dengan disabilitas berarti menambah beban kerja saya).	0.8	The items are relevant and appropriate.
5	Students with disabilities should not be taught in regular classes as it would require too much teacher time (Siswa dengan disabilitas tidak seharusnya diajarkan di kelas reguler karena akan membutuhkan terlalu banyak waktu guru)	0.7	The items are relevant and appropriate.
6	Students with disabilities should be taught alongside students without disabilities in regular classes where possible (Siswa dengan disabilitas seharusnya diajarkan bersama siswa tanpa disabilitas di kelas reguler jika memungkinkan)	0.85	The items are relevant and appropriate.
Impact on Student Learning			
7	Students without disabilities will learn to work together in achieving goals when they learn alongside students with disabilities (Siswa tanpa disabilitas akan belajar bekerja sama dalam mencapai tujuan ketika mereka belajar bersama siswa dengan disabilitas)	0.84	The items are relevant and appropriate.
8	The presence of students with disabilities in the regular class will motivate students without disabilities to improve their motor skills (Kehadiran siswa dengan disabilitas di kelas reguler akan memotivasi siswa tanpa disabilitas untuk meningkatkan keterampilan motorik mereka)	0.8	The items are relevant and appropriate.
9	Students with disabilities will learn faster if taught in regular classes with students without disabilities (Siswa dengan disabilitas akan belajar lebih cepat jika diajarkan di kelas reguler bersama siswa tanpa disabilitas)	0.75	The items are relevant and appropriate.
10	Students with disabilities will develop a more positive self-concept when they learn motor skills with classmates without disabilities (Siswa dengan disabilitas akan mengembangkan konsep diri yang lebih positif ketika mereka belajar keterampilan motorik bersama teman sekelas tanpa disabilitas)	0.88	The items are relevant and appropriate.
Need for additional training			
11	As a physical education teacher, I feel that I do not have enough training to teach students with disabilities alongside students without disabilities in regular classes (Sebagai guru pendidikan jasmani, saya merasa tidak memiliki pelatihan yang cukup untuk mengajar siswa dengan disabilitas bersama siswa tanpa disabilitas di kelas reguler)	0.82	The items are relevant and appropriate.
12	As a physical education teacher, I need additional training to be able to teach classes with students with and without disabilities (Sebagai guru pendidikan jasmani, saya membutuhkan pelatihan tambahan untuk dapat mengajar kelas dengan siswa disabilitas dan tanpa disabilitas)	0.87	The items are relevant and appropriate.

Attitude Toward Teaching Individuals with Disabilities III (PEATID III) instrument through consultation with three experts in the field of physical education and inclusive education. To ensure the accuracy of the translation, a translation and back-translation process was conducted. The next stage was the initial pilot test, where the instrument was tested on 20 physical education teachers to assess the clarity of the language and instructions delivered. The results of this stage were used to make minor revisions to the instrument. Next, the data collection process was carried out by visiting previously approved schools. Respondents were given an explanation of the purpose of the study and guidelines for completing the instrument, which lasted for 15-20 minutes under the supervision of the researcher. Before the instrument was used for large-scale data collection, content validity was evaluated by five experts with backgrounds in inclusive physical education, psychometrics, and instrument adaptation, using the Content Validity Ratio (CVR) method. The final stage involved data processing, where the collected data was analyzed using statistical software to ensure the reliability and validity of the instrument in the context of this study.

Statistical Analysis

Data analysis in this study was conducted using IBM SPSS and AMOS software through three main stages, based on the approach recommended by Field (2017). First, we checked the PEATID III instrument's construct validity using confirmatory factor analysis (CFA) with AMOS, following model evaluation criteria like χ^2/df , CFI, and RMSEA (Byrne, 2016). Then, we checked the instrument's reliability using Cronbach's alpha coefficient with SPSS; a value of 0.70 or higher is considered good (Kline, 1999). Second, descriptive analyses were conducted using SPSS to describe the distribution of respondents' attitudes toward teaching students with disabilities based on the aspects measured, including means, standard deviations, and frequency distributions. Thirdly, the Pearson correlation test was applied to assess the relationship between respondents' characteristics, such as age, teaching experience, and training attended, and their attitudes toward inclusive education, as proposed by Field (2017). This approach was designed to provide comprehensive insights into the validity and reliability of the instrument, the distribution of attitudes, and the factors that influence teachers' attitudes.

Results

Instrument Validity and Reliability

The results of the PEATID III instrument validity and reliability tests showed that this instrument has adequate measurement quality in the context of physical education in Indonesia. Content validity was assessed using the Content Validity Ratio (CVR), where all items had values above the minimum threshold of 0.60. This finding indicates that each item in the instrument is relevant and appropriate to the Indonesian social and cultural context, making it suitable for measuring teachers' attitudes toward teaching students with disabilities (Table 2).

Furthermore, construct validity was tested using Confirmatory Factor Analysis (CFA). The CFA results showed that the three-factor model measured by the instrument fit the research data, with values of $\chi^2/df = 2.31$, CFI = 0.93, and RMSEA = 0.06. This model fit shows that the factor structure used to measure teacher attitudes with the PEATID III tool works well with the data that was collected (Table 3).

Table 3. Construct validity (CFA)

Indicator	Value	Suitability Criteria
χ^2/df	2.31	≤ 3.0
CFI	0.93	≥ 0.90
RMSEA	0.06	≤ 0.08
Conclusion	The model fits the research data	

In terms of reliability, measurement using Cronbach's alpha coefficient yielded satisfactory values. The first factor, covering the teaching outcomes of students with disabilities, had a reliability value of $\alpha = 0.85$, indicating a high level of reliability. The second factor, which measures the impact on students' overall learning, demonstrated a high level of reliability, with a reliability score of 0.79. The third factor, the need for additional training, achieved $\alpha = 0.82$, also indicating excellent reliability. Overall, the total scale had a Cronbach's alpha value of 0.88, which represents an excellent level of reliability for measuring teachers' attitudes toward teaching students with disabilities (Table 4).

Table 4. Instrument reliability

Factor	Cronbach Alpha Coefficient (α)	Reliability Criteria
Factor 1: Teaching Outcomes of Students with Disabilities	0.85	High reliability
Factor 2: Impact on Student Learning	0.79	Good reliability
Factor 3: Need for Additional Training	0.82	Good reliability
Total Scale	0.88	Very good reliability

These results confirm that the PEATID III instrument has met the criteria for strong validity and reliability in the local context. As such, it can be used as a reliable tool to evaluate the attitudes of physical education teachers in Indonesia and support policy development and training aimed at improving educational inclusion.

Distribution of Teachers' Attitudes

A descriptive analysis shows that teachers' attitudes toward teaching students with disabilities tend to be positive. The mean total score of the PEATID III scale was 3.87 (SD = 0.64), with the highest score on the Impact on Student Learning factor (M = 4.12, SD = 0.53). The factor indicating the need for additional training had a lower mean score (M = 3.65, SD = 0.71), suggesting that many teachers perceived a need for additional training to effectively teach students with disabilities (Table 5).

Table 5. Descriptive statistics and reliability of PEATID III

Factor	Average Score	SD	Reliability (α)
Teaching Outcome	3.87	0.64	0.85
Learning Impact	4.12	0.53	0.79
Training Needs	3.65	0.71	0.82
Total Scale	3.87	0.64	0.88

Relationship between teacher characteristics and attitudes

The results of the correlation analysis showed a significant association between student teaching experiences with disabilities and positive attitudes toward inclusive education ($r = 0.45$, $p < 0.01$). Teachers with more than five years of experience had higher mean scores on all factors compared to less experienced teachers. In addition, additional training attended by teachers was also positively correlated with scores on the Need for Additional Training factor ($r = 0.38$, $p < 0.05$) (Table 6).

Table 6. Relationship between Teacher Characteristics and Attitudes

Variable	Correlation (r)	Significance (p)
Teaching Experience	0.45	< 0.01
Additional Training	0.38	< 0.05

Discussion

The results of this study indicate that the PEATID III instrument has excellent validity and reliability in the context of physical education in Indonesia. Content validity was assessed through the Content Validity Ratio (CVR), with all items having values above 0.60. This indicates that the instrument is relevant and appropriate to the local culture, supporting Lawshe's findings that CVR can be used to evaluate the relevance of items in specific context-based instruments (Umar & Lian, 2024). Similar findings were also reported by Gabriela (2021), who found that adaptation of culture-based instruments improved measurement accuracy in the context of inclusive education.

An analysis called Confirmatory Factor Analysis (CFA) showed that the three-factor model fit the data well ($\chi^2/df = 2.31$; CFI = 0.93; RMSEA = 0.06). These values correspond to the model fit criteria proposed by Byrne (2016). The resulting factor structure also reflects previous theories on teachers' attitudes towards inclusive education, where attitudes towards learning impacts, teaching outcomes, and training needs are key dimensions (De Boer et al., 2011; Mata & Clipa, 2020).

The reliability of the instrument, with a total Cronbach's alpha value of 0.88, indicates high internal consistency. This reliability is in line with Kline's (1999) recommendation that alpha values above 0.70 indicate an adequate level of reliability. Individual factors, including how well students with disabilities are taught ($\alpha = 0.85$), how this affects their learning (± 0.79), and how much extra training they need (± 0.82), all showed good to excellent reliability. This supports the results from Ewing et al. (2018) study on instruments to measure attitudes towards inclusive education.

The distribution of teachers' attitudes toward inclusive education also tended to be positive, with a PEATID III mean

score of 3.87 (SD = 0.64). The highest score on the student learning impact factor ($M = 4.12$, SD = 0.53) indicates that teachers believe in the social and learning benefits of inclusive teaching. This finding supports the views of Specht and Metsala (2018) and Weber and Greiner (2019) that positive experiences in teaching students with disabilities can increase teachers' belief in the effectiveness of inclusive education. However, the lower score on the additional training needs factor ($M = 3.65$, SD = 0.71) suggests that there is still a need to improve teachers' capacity through relevant training, as identified by Dignath et al. (2022).

The relationship between teacher characteristics and attitudes also provides important insights. Experience teaching students with disabilities showed a significant positive correlation with positive attitudes toward inclusive education ($r = 0.45$, $p < 0.01$). Teachers with more than five years of experience had higher scores compared to less experienced teachers. This is supported by several studies that found that teachers with more experience have more negative attitudes toward inclusion (Triviño-Amigo et al., 2022). In addition, additional training attended by teachers was also positively correlated with scores on the additional training needs factor ($r = 0.38$, $p < 0.05$), indicating the importance of developing local needs-based training programs to improve teachers' readiness for the challenges of inclusive education.

However, this study has some limitations that need to be considered. Firstly, the local context specific to physical education in Indonesia means that the results of this study may not be fully generalisable to education systems in other countries. The validity of the PEATID III instrument needs to be further tested in different cultural environments to ensure its adaptability. Secondly, this study only involved participants from Pekanbaru City, while Indonesia has many regions with different cultural diversity, educational access, and facilities. This limitation may affect the generalisability of the findings, so future studies should cover a wider area and be nationally representative.

In addition, although the sample size was sufficient for analysis, there was under-representation of teachers from remote areas or with limited access to training. The study's cross-sectional approach also hindered the evaluation of changes in teachers' attitudes over time, particularly after receiving additional training or gaining more experience in teaching children with disabilities. The study was also limited to measuring three main factors of teachers' attitudes: the outcomes of teaching students with disabilities, the impact on student learning, and the need for additional training. Other factors, such as administrative support, availability of facilities, or community perceptions of inclusive education, have not been explored in this study.

As a recommendation, future research could use a longitudinal design to evaluate how additional training and teaching experiences affect teachers' attitudes toward inclusive education over time. In addition, local needs-based training programs designed to improve teachers' capacity to teach students with disabilities should be evaluated for their effectiveness. It is also important to broaden the scope of the research sample to include teachers from different parts of Indonesia, including remote areas, to provide a more representative picture. With this approach, future research is expected to provide deeper insights and support the development of more inclusive policies.

Conclusions

This study shows that the PEATID III instrument has excellent validity and reliability for measuring physical education teachers' attitudes toward teaching students with disabilities in the Indonesian context. The content, construct, and reliability validity of the instrument met the established criteria, with a total Cronbach's α value of 0.88 indicating an excellent level of internal consistency. Descriptive analyses showed that teachers' attitudes tended to be positive, especially in the dimension of student learning impact, although the need for additional training was still a concern. Correlation results also showed that experience teaching students with disabilities and participation in additional training were positively correlated with teachers' attitudes toward inclusive education. Teachers with more than five years of experience tended to have more positive attitudes compared to less experienced teachers.

This study makes an important contribution by providing a reliable instrument to evaluate teachers' attitudes toward inclusive education in the context of physical education in Indonesia. The validity and reliability of the PEATID III instrument can be used by researchers, practitioners, and policymakers to identify training needs and design intervention programs that are better suited to local needs. Additionally, the study's results underscore the significance of hands-on experience teaching students with disabilities and additional training as crucial factors in enhancing teachers' positive attitudes towards inclusive education. This research also provides a foundation for further studies to explore the development of more effective policies and training to support inclusive education in Indonesia. By expanding the scope of the study to include a wider and more representative area, these results are expected to contribute to the development of inclusive education at the national level.

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Conflict of Interest

The author declares no conflict.

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Валідація інструменту з оцінки ставлення викладачів фізичного виховання щодо навчання осіб з інвалідністю III групи (PEATID III) для викладачів фізичного виховання: Підтримка інклюзивної освіти в Індонезії

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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., 34 джерела.

Мета дослідження. Це дослідження мало на меті валідизувати інструмент з оцінки ставлення викладачів фізичного виховання щодо навчання осіб з інвалідністю III групи (PEATID III) в контексті фізичного виховання в Індонезії, зокрема у м. Пеканбару.

Матеріали та методи. У дослідженні взяли участь 120 викладачів фізичного виховання з м. Пеканбару, яких було відібрано за методом цілеспрямованої вибірки. Критерії включення респондентів включали викладачів, які мали досвід навчання учнів з інвалідністю у звичайних класах і виявили готовність взяти участь у цьому дослідженні. З метою вивчення ставлення вчителів фізичної культури до навчання осіб з інвалідністю III (PEATID III) в контексті фізичного виховання застосовано інструмент, що складається із 12 тверджень, які визначають три аспекти ставлення викладачів, а саме: (i) результати навчання учнів з інвалідністю, (ii) вплив на навчання учнів та (iii) потреба в додатковій навчальній підготовці.

Результати. Значення коефіцієнта валідності змісту (CVR) за усіма пунктами перевищували показник 0,60, що вказує на високу релевантність індонезійському соціальному та культурному середовищу. Конструктна валідність перевірялась із використанням методу підтверджуючого факторного аналізу (CFA), який встановив задовільну відповідність моделі ($\chi^2/df = 2,31$; CFI = 0,93; RMSEA = 0,06). Коефіцієнт альфа Кронбаха інструменту склав 0,88, що свідчить про міцну внутрішню узгодженість. Описовий аналіз показав, що ставлення вчителів фізичної культури до навчання учнів з інвалідністю, як правило, було позитивним ($M = 3,87$; $SD = 0,64$). Викладачі з досвідом роботи понад п'ять років і додатковою підготовкою мали більш інклюзивне ставлення.

Висновки. Проведене дослідження робить значний внесок у створення надійного інструменту для оцінки ставлення вчителів до інклюзивної освіти, сприяючи розробленню стратегій і навчальних програм, що відповідають локальним потребам. Отримані результати також створюють основу для подальших досліджень, спрямованих на зміцнення інклюзивної освіти в Індонезії через застосування більш комплексного та репрезентативного підходу.

Ключові слова: валідація, PEATID III, фізичне виховання, інклюзивна освіта.

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Evaluating the Effects of Circuit Training and Motivation on Gender-Specific Waist Reduction in Overweight Populations

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Abstract

Background. Overweight is a global health problem that is closely associated with an increased risk of cardiovascular and metabolic diseases. Waist circumference, as an indicator of visceral fat, serves as an important parameter for assessing the effectiveness of weight loss interventions. Motivation and exercise type, including circuit training, are believed to play significant roles in the success of weight management programs.

Objectives. This study aimed to analyze the influence of motivation, gender, and circuit training methods (isometric and isokinetic) on waist circumference reduction in overweight individuals.

Materials and methods. The study employed a 2×2×2 factorial design with a quasi-experimental approach. Forty participants from a fitness center were divided into eight groups based on the combinations of motivation (high and low), gender, and training method (isometric and isokinetic). Waist circumference data were measured before and after the treatment over 16 training sessions, with data analysis performed using three-way ANOVA.

Results. Isokinetic training showed higher effectiveness in reducing waist circumference compared to isometric training, with high motivation being a factor that enhanced results. Conversely, gender did not have a substantial effect on waist circumference reduction. Motivation and exercise type had significant main effects ($p < 0.001$), while a marked interaction was found between motivation and exercise type ($p < 0.01$), highlighting the importance of combining these two factors.

Conclusions. Motivation and circuit training methods are key factors in the success of waist circumference reduction, with isokinetic training recommended as the primary choice for optimal results. These findings provide practical guidelines for designing more effective and inclusive physical activity-based overweight management programs.

Keywords: overweight, waist circumference, circuit training, motivation.

Introduction

Overweight constitutes one of the most pressing public health challenges globally. This is due to the global increase in childhood overweight, especially its impact on long-term health (Muyulema et al., 2024). This condition can also be described as an excessive buildup of adipose tissue, which adversely impacts health (Fauziyah & Rohmawati, 2019). Being overweight increases the risk of non-communicable diseases (NCDs), such as cardiovascular disease, diabetes,

cancer, and respiratory disease (Alsla et al., 2024). The World Health Organization (WHO) has indicated that Overweight has escalated to a global epidemic, impacting millions worldwide (WHO, 2019). Furthermore, Overweight is directly correlated with several chronic diseases, including type 2 diabetes, hypertension, cardiovascular disease, and osteoarthritis, all of which contribute to increased global morbidity and mortality (Amad Syarifudin & Nurmala, 2015; Al-Mhanna et al., 2024). In addition, major risk factors for various non-communicable diseases and mortality are caused by obesity and low cardiorespiratory fitness (Rago & Mohr, 2023).

Overweight is a disease that adversely affects quality of life, mortality and morbidity, and is associated with a

sedentary lifestyle (John et al., 2023). Childhood overweight remained a significant health issue that necessitated customized treatment approaches. The findings indicated that short-term lifestyle interventions were more effective in decreasing BMI z-scores and cardiovascular risk factors in pubertal boys compared to girls. Further research was required to explore these gender differences in greater depth to inform the development of tailored interventions (Gilardini et al., 2024). The prevalence of Overweight had risen across all age groups, including children and adolescents. Research indicated that approximately 50% of children and 80% of adolescents who were overweight were likely to maintain this condition into adulthood, thus heightening the risk of chronic health complications in later life (Al-Haifi, 2023). Conversely, Overweight in the elderly was often aggravated by sarcopenia, a decline in muscle mass associated with aging, which further elevated the risk of metabolic and cardiovascular disorders (Jung et al., 2022).

Physical exercise had long been recognized as an effective intervention for reducing Overweight. Among various training methods, circuit training stood out as one of the most popular and effective approaches. This training system integrated both aerobic and anaerobic elements, enhancing cardiovascular fitness, muscle strength, and body fat reduction (Harsono, 2015; Boraczyński et al., 2021). Circuit training offered flexibility and time efficiency, making it suitable for diverse population groups (Rago & Mohr, 2023). Research indicated that circuit training could yield significant benefits within a relatively short duration. This form of exercise not only enhanced VO_2max but also improved metabolic profiles, including lipid levels and insulin resistance. Furthermore, when combined with other methods, such as High-Intensity Interval Training (HIIT), circuit training demonstrated an ability to increase muscle strength and further reduce body fat (Pashaei et al., 2024).

Home-based circuit training programs also showed positive results in improving cardiometabolic fitness among the elderly with comorbidities such as type 2 diabetes and osteoarthritis (Al-Mhanna et al., 2024). In lower socio-economic contexts, circuit training became an ideal solution because it could be done at minimal cost and in a shorter time compared to conventional training methods (Mehmood et al., 2022). However, the success of circuit training was not only determined by the training method itself but also by individual motivation. Motivation was a key element that influenced the success of participation in exercise programs. Research indicated that individuals with high motivation were more likely to adhere to training programs and achieve better results (Batrakoulis et al., 2020). Conversely, a lack of motivation often became a major obstacle in achieving fitness goals. In addition to motivation, gender also played an important role in the effectiveness of physical exercise. Hormonal differences between men and female affected the body's adaptation to physical exercise, especially in terms of reducing visceral fat and increasing cardiovascular capacity (Gilardini et al., 2024). For instance, men tended to show faster metabolic responses to high-intensity training, while female might require a more endurance-focused approach to achieve similar results (Pahlavani et al., 2024).

Considering these factors, home-based circuit training programs could be tailored to meet the needs of various individual groups, ensuring a more personalized and effective

approach to improving cardiometabolic fitness. Although numerous studies have highlighted the benefits of circuit training, there remains a gap in the literature regarding how motivation and gender influence the effectiveness of this exercise, particularly in the context of reducing waist circumference. Most research tends to focus on one or two aspects, such as cardiovascular fitness parameters or body composition, without considering the complex interactions among these factors (Seo et al., 2019). This study aimed to fill that gap by exploring the influence of circuit training methods, exercise motivation, and gender on the reduction of waist circumference in overweight individuals. Waist circumference is recognized as an important indicator for assessing the accumulation of visceral fat. Visceral fat, concentrated around vital organs such as the liver, kidneys, and intestines, is closely linked to the risk of cardiovascular disease, insulin resistance, and metabolic syndrome (Fareed et al., 2017). Measuring waist circumference is also a practical and widely used parameter for evaluating the success of interventions targeting visceral Overweight (Howlader et al., 2018).

The multifactorial approach of this study allowed for a more holistic analysis of the interactions between variables, aiming to provide new insights relevant to fitness practitioners and researchers. Furthermore, this study was designed to contribute practically to the development of more inclusive and effective exercise programs. By exploring how motivation and gender could modify responses to circuit training, the results of this study are expected to help design more personalized interventions tailored to individual needs and applicable on a broader scale. The urgency of this research lies not only in its efforts to enhance the effectiveness of circuit training but also in its potential to support better public health policies. By providing more comprehensive empirical evidence, this study could serve as a foundation for developing intervention programs that systematically address Overweight challenges. The training methods used in this study were isometric and isokinetic circuit training as treatments for reducing waist circumference, with exercise motivation and gender as attribute variables.

Materials and Methods

The Type of Research

The type of research conducted used a quasi-experimental design with a multifactorial approach to examine the influence of several independent variables (circuit training methods, exercise motivation, and gender) on the dependent variable (waist circumference reduction). The study employed a 2×2 factorial design, with groups based on the combinations of the three independent variables. The research was carried out four times a week, resulting in a total of 16 treatment sessions.

Participants

The population in this study consisted of members of Celebrity Fitness Paragon Mall in Semarang, Indonesia, totaling 50 individuals. To determine the sample, the researcher used purposive sampling technique. Based on predetermined criteria, the top 20 individuals with high

exercise motivation and the last 20 individuals with low exercise motivation were selected as samples, resulting in 40 samples. These samples were then divided into 8 groups. From these 8 groups, 2 main groups were formed to undergo treatment: one group for isometric training and another for isokinetic training. Each of these main groups was further divided into two subgroups based on gender, resulting in male and female training groups for both isometric and isokinetic exercises.

Instrument

The data collection techniques used in this study involved tests and measurements. Two types of data were collected: 1) Waist circumference was measured using Metline, which is useful for measuring distances that are straight, angular, or circular. Waist circumference measurements were taken before and after the treatment to determine the Gain achieved by participants, which was then analyzed. 2) The instrument used to collect data on exercise motivation was a questionnaire. This questionnaire utilized a modified Likert scale with four answer choices: strongly agree, agree, disagree, and strongly disagree. The scale included four alternative answers: Strongly Agree (SA) with a score of 4, Agree (A) with a score of 3, Disagree (D) with a score of 2, and Strongly Disagree (SD) with a score of 1.

Statistical Analysis

Given that this study involved several independent variables (training methods, motivation, and gender) and one dependent variable (waist circumference reduction), the data analysis technique used was a 3-Way Factorial Analysis of Variance (3-Way ANOVA). This analysis aimed to evaluate the effects of three independent variables: training methods (with two levels: isometric and isokinetic), motivation (with two levels: high and low), and gender (male and female) on the dependent variable, which was waist circumference reduction. This approach allowed researchers to examine the main effects of each independent variable, the interactions between two independent variables, and the interaction among all three independent variables simultaneously.

The analysis began with testing the main effects to determine if each independent variable individually influenced waist circumference reduction. Following this, the interactions between two independent variables were analyzed to identify possible interactive relationships between the combinations of two variables. The study also included testing the interactions among all three independent variables to explore the complex influence of training methods, motivation, and gender on waist circumference reduction. When main effects or interactions were found to be significant, further analysis was conducted through post-hoc tests, such as Tukey HSD or Bonferroni, to identify specific groups showing significant differences.

It was crucial to ensure the assumptions of ANOVA, such as data normality and homogeneity of variances among groups, were met. However, since the data were not normal, alternative non-parametric methods, like the Kruskal-Wallis test for main effects or rank-based ANOVA for interactions, were used. Additionally, if significant interactions were found, simple effects analysis was performed to gain deeper insights

into how a particular independent variable influenced the dependent variable under specific conditions of the other independent variables. To support the interpretation of results, visualization in the form of interaction plots was used. One such graphical form was the profile plot, which displayed the patterns of relationships among the levels of independent variables. These plots included error bars to depict the 95% confidence intervals, making the results more intuitively understandable.

Results

Based on the descriptive statistics presented on table 1, data analysis was conducted to understand the influence of the combination of motivation, gender, and type of exercise on waist circumference reduction. These variables were grouped into various combinations, and the data were summarized in terms of mean, standard deviation, and the number of participants (n) for each group.

In the low motivation group, males who participated in isometric exercises experienced an average waist circumference reduction of -1.80 with a standard deviation of 0.84, indicating some individual variability. In contrast, males in the isokinetic exercise group had a greater average reduction of -2.40, with a smaller standard deviation (0.55), indicating more consistent results. Overall, the combined average reduction for males with low motivation was -2.10 with a standard deviation of 0.74. For females, similar results were observed, with an average reduction of -1.60 in the isometric exercise group and -2.40 in the isokinetic exercise group. The variability of results among females remained low in both types of exercise, with a combined average reduction of -2.05 and a standard deviation of 0.69.

In the high motivation group, more significant results were found. Males in the isometric exercise group recorded an average waist circumference reduction of -2.60 with a low standard deviation (0.55), while the isokinetic exercise group showed a much larger average reduction of -4.60, with very small variability (0.55). The total combined average reduction for males with high motivation was -3.60 with a standard deviation of 1.18. High motivation females showed nearly similar results, with an average reduction of -2.40 in the isometric exercise group and -4.60 in the isokinetic exercise group, resulting in a combined average reduction of -3.55 with a standard deviation of 1.19. This indicates that high motivation significantly contributed to waist circumference reduction, especially in the isokinetic exercise group.

Overall, the combined average reduction in waist circumference for males was -2.85 with a standard deviation of 1.23, while for females it was -2.75 with a standard deviation of 1.25. Isometric exercises produced an average reduction of -2.10 with low variability (standard deviation 0.78), while isokinetic exercises resulted in a larger reduction of -3.50 with higher variability (standard deviation 1.23). The thematic analysis showed that isokinetic exercises consistently produced better results compared to isometric exercises, regardless of motivation levels or gender. High motivation had a more significant impact on waist circumference reduction, particularly in the isokinetic exercise group. For low motivation groups, males tended to have a greater reduction in waist circumference compared

to females, but in the high motivation groups, this difference became insignificant, with results nearly equal between genders.

Table 1. Descriptive statistics data of the combination of motivation, gender, and type of exercise

Circuit Traininnng	Motivation	Gender	Mean	Std. Deviation	n
Isometric	Lower	Male	-1.80	0.84	5
		Female	-1.60	0.55	5
		Total	-1.70	0.67	10
	High	Male	-2.60	0.55	5
		Female	-2.40	0.55	5
		Total	-2.50	0.53	10
	Total	Male	-2.20	0.79	10
		Female	-2.00	0.67	10
		Total	-2.10	0.72	20
Isokinetic	Lower	Male	-2.40	0.55	5
		Female	-2.40	0.55	5
		Total	-2.40	0.52	10
	High	Male	-4.60	0.55	5
		Female	-4.60	0.55	5
		Total	-4.60	0.52	10
	Total	Male	-3.50	1.27	10
		Female	-3.50	1.27	10
		Total	-3.50	1.24	20
Total	Lower	Male	-2.10	0.74	10
		Female	-2.00	0.67	10
		Total	-2.05	0.69	20
	High	Male	-3.60	1.17	10
		Female	-3.50	1.27	10
		Total	-3.55	1.19	20
	Total	Male	-2.85	1.23	20
		Female	-2.75	1.25	20
		Total	-2.80	1.22	40

Dependent Variable: abdominal circumference

The Analysis of Variance (ANOVA) conducted in this study evaluated the influence of motivation, gender, and type of exercise (Circuit Training) on waist circumference reduction, as well as the interaction among these independent variables (see table 2). The resulting statistical model demonstrated a high explanatory power, with an R-Squared value of 0.808, indicating that 80.8 % of the variability in waist circumference reduction could be explained by the combination of variables in the model. The Adjusted R-Squared value of 0.766 further reinforced the accuracy of this model after adjusting for the number of predictors used.

The analysis results indicated that motivation had a significant impact on waist circumference reduction. With an F-value of 64.286 ($p < 0.001$) and Partial Eta Squared (η^2) of 0.668, motivation accounted for approximately 66.8 % of

the data variability. This finding underscored the importance of motivation in achieving significant waist circumference reduction. Conversely, gender did not have a significant impact on waist circumference reduction, with an F-value of 0.286 ($p = 0.597$) and η^2 of only 0.009, suggesting that gender contributed minimally to the data variability, less than 1%. The type of exercise, or Circuit Training, was also found to have a significant impact on waist circumference reduction, with an F-value of 56.000 ($p < 0.001$) and η^2 of 0.636. This indicated that the type of exercise accounted for 63.6% of the variability in waist circumference, making it a crucial factor in determining the outcomes of the training program. Further interaction analysis showed that the effect of motivation on waist circumference was not influenced by gender, as evidenced by the non-significant Motivation*Gender interaction ($F = 0.000$, $p = 1.000$, $\eta^2 = 0.000$). Additionally, the interaction between gender and type of exercise was also non-significant ($F = 0.286$, $p = 0.597$, $\eta^2 = 0.009$), indicating that the impact of the type of exercise did not differ substantially between males and females.

However, a significant interaction was found between motivation and type of exercise, with an F-value of 14.000 ($p = 0.001$) and η^2 of 0.304. This finding indicated that the effectiveness of the type of exercise on waist circumference reduction was highly dependent on the participants' level of motivation, with the interaction contributing 30.4 % to the data variability. On the other hand, the three-way interaction of Motivation*Gender*Circuit Training did not show a significant influence on waist circumference reduction ($F = 0.000$, $p = 1.000$, $\eta^2 = 0.000$). The analysis results were further supported by the observed power of the relevant variables. Motivation and type of exercise had an observed power of 1.000, indicating a high ability to detect significant effects. Conversely, the non-significant interactions, such as Motivation*Gender or Gender*Circuit Training, had low observed power (0.050–0.081), reflecting their inability to detect small or weak effects.

Overall, this study demonstrated that motivation and type of exercise were the primary factors contributing significantly to waist circumference reduction, with substantial contributions from each ($\eta^2 = 0.668$ and $\eta^2 = 0.636$, respectively). Gender did not have a significant influence, either independently or in its interaction with other variables. The significant interaction between motivation and type of exercise indicated that the effectiveness of the exercise type was highly dependent on the participants' motivation level. With an R^2 value of 0.808, this model provided a very strong explanation for the changes in waist circumference observed in the tested exercise programs.

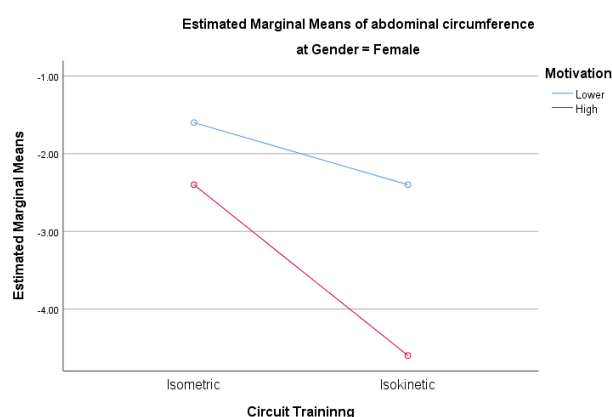
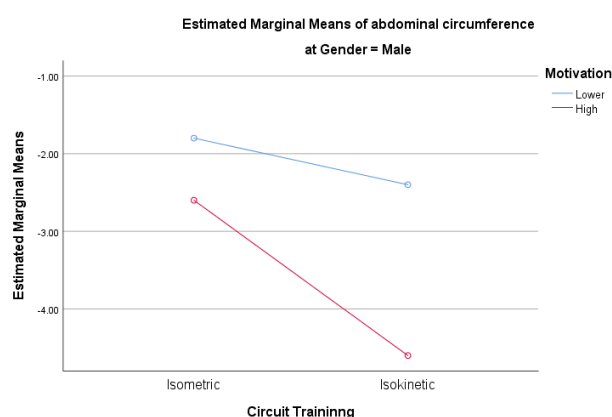
The factorial test plots in graphic 1 revealed the interaction between the type of circuit training (Isometric and Isokinetic) and the level of motivation (low and high) on waist circumference reduction in female. Generally, Isokinetic training resulted in a greater reduction in waist circumference compared to Isometric training, indicating higher effectiveness. In the Isometric training group, the difference between participants with low and high motivation was small, with the high motivation group showing a slightly better reduction in waist circumference. However, in the Isokinetic training group, this difference became much more significant, with the high motivation group showing

Table 2. The analysis of variance (ANOVA) with tests of between-subjects effects

Dependent Variable: abdominal circumference								
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power ^b
Corrected Model	47.200 ^a	7	6.743	19.26	.00	.81	134.86	1.00
Intercept	313.60	1	313.60	896.00	.00	.97	896.00	1.00
CircuitTraining	19.60	1	19.60	56.00	.00	.64	56.00	1.00
Motivation	22.50	1	22.50	64.29	.00	.67	64.29	1.00
Gender	.10	1	.100	.29	.60	.01	.29	.09
CircuitTraining * Motivation	4.90	1	4.90	14.00	.001	.30	14.00	.96
CircuitTraining * Gender	.100	1	.10	.29	.60	.01	.29	.08
Motivation * Gender	.00	1	.00	.00	1.00	.00	.00	.050
CircuitTraining * Motivation * Gender	.00	1	.00	.00	1.00	.00	.00	.050
Error	11.20	32	.35					
Total	372.00	40						
Corrected Total	58.400	39						

a. R Squared = .808 (Adjusted R Squared = .766)

b. Computed using alpha = .05

**Fig. 1.** The factorial test plots the interaction analysis in female**Fig. 2.** The factorial test plots the interaction analysis in male

a much larger reduction in waist circumference compared to the low motivation group. Furthermore, the level of motivation proved to be crucial in determining outcomes,

with highly motivated individuals consistently achieving greater reductions in waist circumference, regardless of whether they were in the Isometric or Isokinetic training group. The observed interaction effects indicated that Isokinetic training became significantly more effective when participants had high motivation. Conversely, the effect of motivation was not as pronounced in the Isometric training group. Overall, these results highlight that the combination of Isokinetic training and high motivation has the greatest impact on reducing waist circumference in female.

Similar results were observed in the plots for male (see graphic 2), where high motivation had a much greater effect on Isokinetic training compared to low motivation. In Isometric training, the difference between high and low motivation was also smaller, though the effect of the exercise was still evident. Overall, these interactions demonstrate that the type of exercise and motivation level have a combined effect on waist circumference reduction. Isokinetic training was more effective in reducing waist circumference, especially for individuals with high motivation. Conversely, Isometric training showed more uniform effects regardless of motivation level. These findings underscore the importance of considering both the type of exercise and the level of motivation in fitness intervention programs for optimal results.

Discussion

The findings from this research indicate that motivation and the type of exercise (circuit training) play a crucial role in reducing waist circumference, while gender does not significantly influence this change. This suggests that individuals with high levels of motivation tend to be more successful in reducing their waist circumference because they are more committed to the exercise program. This result aligns with research by Bruseghini et al. (2019), which revealed that high-intensity training combined with verbal motivation results in significant reductions in body

fat, including waist circumference. Furthermore, high motivation encourages participants to remain consistent with high-intensity training (Gonçalves et al., 2023). Additionally, strong internal motivation significantly impacts the improvement of body composition (Jee, 2019).

The interaction between motivation and type of exercise was also found to be significant, indicating that the effectiveness of exercise depends greatly on the participant's motivation level. These results prove that motivation from training is important for adherence and outcomes (Marcos-Pardo et al., 2019). There are forms of motivation that can be provided in the form of verbal encouragement and goal-oriented strategies (Davis et al., 2011). Highly motivated individuals can achieve greater results from circuit training compared to those who are less motivated. Consequently, high motivation has a more significant impact on waist circumference reduction. For individuals with low motivation, men tend to experience greater waist circumference reduction compared to women, but at high motivation levels, this difference becomes insignificant, with nearly equal results between genders. Conversely, gender did not show a significant influence either independently or in its interaction with other variables, indicating that gender differences do not affect the results of waist circumference reduction achieved. Therefore, motivation and the type of exercise (circuit training) are crucial in reducing waist circumference, while gender does not significantly impact these changes.

Circuit training was found to have a significant impact on waist circumference reduction, explaining 63.6% of the data variability. This indicates that circuit training is an effective method for reducing waist circumference by incorporating various high-intensity movements that efficiently burn calories. This result is supported by previous research showing that high-intensity circuit training is effective in managing overweight individuals (Malarvizhi et al., 2017). An eight-week full-body circuit training program can improve cardiorespiratory fitness and body composition in overweight individuals (Rago & Mohr, 2023). Moreover, circuit training can be an effective exercise method for improving cognitive risk factors in elderly Korean women with Overweight (Kang et al., 2024). Circuit training also contributes to the aerobic portion of guidelines for adults living with Overweight (Keshavarz et al., 2024).

Thematic analysis revealed that isokinetic exercises consistently produced greater results compared to isometric exercises, regardless of motivation levels or gender. This finding aligns with previous research indicating that isokinetic training programs combined with aerobic exercises result in significant weight loss and body fat reduction, including waist circumference (Ghroubi et al., 2016). Additionally, isokinetic resistance training combined with aerobic interval training significantly reduces waist circumference and metabolic disease risks (Bruseghini et al., 2015). Furthermore, isokinetic training reduces pain and increases muscle strength for overweight women (Hammami et al., 2024). Isokinetic training is also effective in reducing waist circumference and improving cardiometabolic fitness (Marc-Hernández et al., 2019). Therefore, isokinetic training is recommended for more significant and consistent results, while efforts to enhance participant motivation should also be prioritized.

The implications of these findings are that effective exercise programs must consider participant motivation as a key factor in designing and implementing workouts. Programs that can enhance motivation, such as by setting clear goals and providing positive feedback, will be more effective in encouraging participants to achieve optimal results. Additionally, circuit training can be a primary choice in waist circumference reduction programs, given its proven effectiveness. Exercise programs should also be tailored to the motivation levels of participants, as more motivated individuals will achieve better results from more intensive workouts. Low motivation leads to major problems and poor adherence to exercise programs resulting in physical inactivity (Collado-Mateo et al., 2021). In addition, motivation determines the appropriateness of a person in doing exercise activities that affect the level of fat in the body (Picorelli et al., 2014). Overall, the results of this study indicate that the main focus in designing waist circumference reduction programs should be on enhancing motivation and using effective exercises like circuit training, without the need to differentiate based on gender. The hope is that this motivation will result in people continuing to do the activity at home (unsupervised) with the same impact as supervised training (Jansons et al., 2016).

Conclusion

This study convincingly demonstrated that motivation and type of exercise (circuit training) had a significant impact on reducing waist circumference in overweight individuals. Isokinetic training proved to be more effective than isometric training in reducing waist circumference in both low and high motivation groups. These findings highlight the importance of choosing the right type of exercise in weight management programs, especially for individuals aiming to reduce visceral fat accumulation associated with serious health risks. Motivation emerged as a key element in the success of exercise programs, with highly motivated individuals showing far more significant results compared to those with low motivation. This underscores the importance of psychological support and strategies to boost motivation when designing fitness programs. Strategies such as setting clear goals, providing constructive feedback, and creating a supportive environment can help encourage higher levels of commitment. Conversely, gender did not have a significant impact on waist circumference reduction, indicating that the effectiveness of circuit training and motivation does not depend on biological differences between men and women. These findings support the argument that circuit training-based fitness programs can be universally applied without requiring special adjustments based on gender.

The practical implications of these findings are crucial for developing more effective and inclusive Overweight intervention programs. By prioritizing motivation and selecting optimal exercise methods like isokinetic circuit training, weight loss programs can become more efficient and have a broader impact. Future research with a wider population scope and multifactorial approach is recommended to ensure the validity of these findings and to explore additional factors that might influence the results. Overall, this study provides significant contributions to the literature on Overweight management and opens

opportunities for more personalized and effective exercise-based interventions.

This study does have some limitations. Firstly, the subjects were limited to members of one fitness center, so generalizing the results to a broader population may require caution. Secondly, the relatively short duration of the study might limit the assessment of the long-term effects of the tested training methods. Therefore, further studies are recommended to involve more diverse participants, including individuals from different social, cultural, or fitness backgrounds. Extending the intervention duration could also help evaluate the long-term effects of the training methods used, including potential declines in motivation or body adaptations to the exercise.

Conflict of Interest

Authors declare no conflict of interest regarding this paper.

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Оцінка впливу методу колового тренування та рівня мотивації на гендерно-специфічне зменшення талії у групах населення з надмірною вагою

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

Реферат. Стаття: 98 с., 2 табл., 2 рис., 35 джерел.

Історія питання. Надмірна вага є глобальною проблемою охорони здоров'я, яка тісно пов'язана з підвищеним ризиком розвитку серцево-судинних і метаболічних захворювань. Окружність талії, як показник вісцерального жиру, виконує функцію важливого параметра оцінки ефективності інтервенцій, спрямованих на зниження маси тіла. Вважається, що мотивація і тип фізичних вправ, включаючи колові тренування, відіграють значну роль в успішному впровадженні програм із контролю ваги.

Мета дослідження. Метою цього дослідження було проаналізувати вплив мотивації, гендеру та методів колового тренування (ізометричного та ізокінетичного) на зменшення окружності талії в осіб з надмірною вагою.

Матеріали та методи. У дослідженні застосовано факторний дизайн 2×2×2 із квазіекспериментальним підходом. Сорок учасників з фітнес-центру було розподілено на вісім груп залежно від комбінації рівня мотивації (високий і низький), гендеру та методу тренувань (ізометричний та ізокінетичний). Дані щодо окружності талії вимірювались перед початком та після завершення курсу впродовж 16 тренувань, а аналіз даних проводився за допомогою трифакторного дисперсійного аналізу (ANOVA).

Результати. Ізокінетичні тренування показали вищу ефективність у зменшенні окружності талії порівняно із ізометричними тренуваннями, причому високий рівень мотивації був чинником, який сприяв покращенню результатів. Натомість гендер не мав суттєвого впливу на зменшення окружності талії. Мотивація і тип фізичних вправ суттєво впливали на результати ($p < 0,001$), тоді як між мотивацією і типом вправ спостерігалася значна взаємодія ($p < 0,01$), що підкреслює важливість поєднання цих двох чинників.

Висновки. Мотивація та методи колового тренування є ключовими факторами для досягнення успішного результату в питаннях щодо зменшення окружності талії, причому для реалізації оптимальних результатів рекомендується застосовувати метод ізокінетичних тренувань в якості пріоритетного варіанта. Отримані дані надають практичні рекомендації для розроблення більш ефективних та інклюзивних програм із контролю надмірної маси тіла, що ґрунтуються на принципах фізичної активності.

Ключові слова: надмірна вага, окружність талії, колове тренування, мотивація.

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The Influence of Small-Sided Games and Floaters Intervention on Physical Components of Soccer Players

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Abstract

Background. In soccer, numerical superiority enhances the effectiveness of both offensive and defensive actions performed by players. To improve the performance of the players, small-sided games (SSGs) with numerical inferiority and superiority should be incorporated into training sessions. Objectives. The study aimed to evaluate the effect of a 12-week training program using floaters and small-sided games (SSGs) on the physical performance of soccer players.

Materials and methods. A total of 52 soccer players participated in the study. The age ranged from 14 to 16 years. The participants were divided into small-sided games with the floater's group (Group I, SSGs+Floaters, n = 26) and the control group (Group II, n = 26). A 12-week program of small-sided games with floaters intervention was completed by the experimental group, who trained five days per week. Each session lasted 90 minutes, including warming up, small-sided games incorporating floaters intervention, lead-up games, and cooling down. The control group did not practice the floaters training program. The Yo-Yo intermittent recovery level 1 test was used to assess maximal aerobic endurance (VO₂max), the Sargent jump test measured leg explosive strength, the Illinois agility test assessed soccer-specific agility, and the 50-meter sprint test evaluated speed. A paired t-test was conducted to measure the within-group differences from pre- to post-test, while the effects of the training were evaluated using ANCOVA and effect size analysis.

Results. The results indicated that small-sided games with floaters intervention significantly improved maximal aerobic endurance, leg explosive strength, and agility except speed. In contrast, the control group did not demonstrate similar improvements. Furthermore, there was a significant difference between the experimental and control groups in maximal aerobic endurance, leg explosive strength, and agility, although speed did not show such a difference.

Conclusions. The findings of this study suggest that implementing small-sided games with floaters intervention can effectively enhance physical performance variables in junior soccer players.

Keywords: small-sided games, floaters training, VO₂max, agility, leg explosive strength, speed.

Introduction

Soccer is a highly complex sport that demands proficiency in all areas of performance. To attain success in soccer, the players must excel in technical, physical, tactical, and mental skills (Kusuma et al., 2024). It is an intermittent sport, and one of the crucial factors for success is physical fitness; the players need to develop and enhance both their aerobic and anaerobic endurance (Michailidis et al., 2024). It is well-known in high-performance sports that exercises are most effective when closely resembling competition demands (Mallo & Navarro, 2008). Thus, physical variables

can be improved in a manner that is more specific to soccer than simply engaging in running alone (Hoff et al., 2002). To incorporate the actual game conditions into training, coaches aim to replicate the physical, technical, and tactical requirements by adapting tasks to the specificity of the game, simplifying their forms, and aligning training objectives accordingly (Kvas-Cabral et al., 2022; Vella et al., 2022).

The implementation of drill-based activities, such as small-sided games (SSGs), has become popular and prevalent in the last decade in soccer training for all ages and levels. SSGs help to improve physical fitness and technical and tactical skills (Halouani et al., 2014). The SSGs, played on smaller pitches with fewer players, have become prevalent for optimizing training time and improving soccer-specific fitness and match-winning skills (Clemente et al., 2014),

which is a challenging, adaptable, fun, and social exercise where participants of all ages can combine high-intensity aerobic endurance, and strength training (Krustrup et al., 2016). The SSGs can emphasize player interactions due to the smaller number of players and smaller playing areas and impose intense physical demands (Clemente et al., 2014). SSGs involve modifications in pitch size (Clemente & Sarmiento, 2020), using modified rules (Castellano et al., 2013) involving fewer players (Selmi et al., 2020), which are crucial for developing technical, tactical, and physiological outcomes (Hill-Haas et al., 2011; Rampinini et al., 2007). The SSGs are classified as small-sided (< 4 vs. 4), medium-sided (MSGs) (5 vs. 5 to 8 vs. 8), and large-sided (LSGs) (9 vs. 9) games (Owen et al., 2012).

The SSGs help to provide the ability to replicate the complicated characteristics of a competitive match by providing random situations and situational interference (Sarmiento et al., 2018). Participating in SSGs enhances learning and contributes to the development of soccer players. SSGs enable coaches to create and control particular task constraints, such as numerical relationships, that influence players in exploring and finding solutions to their ability to adapt their behaviors to circumstances that are constantly changing (Davids et al., 2013). Manipulating task constraints in SSGs appears to be an effective method for skill acquisition (Francesco Sgrò et al., 2018). A commonly manipulated numerical relations constraint in SSGs is using floaters (Castellano et al., 2016). Changing the number of players introduces temporary “overload” and “under load” circumstances between the opposite teams through a “floater” player. The effect of incorporating floaters in SSGs is one of the most trending and frequently investigated task constraints (Moreira Praça et al., 2017).

The “floater” is a player who always plays with the team in possession during SSGs, providing numerical superiority (Lacome et al., 2018). The coaches aim to create an imbalance by including floater players, which makes the SSGs drill more reflective of real game scenarios because soccer often involves numerical imbalances, whether temporarily or permanently. This unbalanced training pattern facilitates ball retention and generates temporary ‘overload’ and ‘underload’ situations, improving defensive and attacking skills and increasing the physical load on the floater (Hill-Haas et al., 2010, 2011). This neutral (floater) player switches to the team in possession of the ball, creating these temporary situations. However, (Nagy et al. 2020) explained that as the number of “neutral” players (floaters) increased, the intensity of the small-sided games gradually decreased.

The floaters are typically used in two different manners: as in-floaters, they are positioned inside the pitch as regular players, switching teams every time ball possession changes while always remaining in the attack (Lacome et al., 2018). (Moniz et al., 2020) suggest that using inside floaters influences physical, technical, and collective tactical behavior. The second one is out-floaters, who stay on the sidelines and serve as an option for players in possession to perform wall passes (Castellano et al., 2016). (Lacome et al., 2018) reported that coaches often use floater players to manage the load of certain players. Their multifunctional nature and the use of floaters boost intensity, making them ideal for replicating the movement demands, physiological intensity, and technical requirements of competitive play.

Although previous studies have provided extensive information on the use of floaters during SSGs, there is a gap in the investigation regarding possible changes in training using floaters and SSGs on the physical performance of soccer players. Physical variables have been identified as one of the primary factors influencing performance in sports. Thus, this study aimed to assess the effect of 12 weeks of SSGs with floaters training on the physical performance of soccer players, specifically focusing on maximal aerobic endurance, leg explosive strength, agility, and speed.

Materials and Methods

Participants

The protocol for the investigation is summarised in Figure 1. To conduct this study, 52 football players selected from two academies (S.M.R.C. Kollemcode and S.B.F.A. Poovar) in Trivandrum, Kerala, India, were chosen. The age ranges from 14 to 16 years, and the players have a minimum of three years of experience in soccer. The participants were divided into two groups, each with 26 players. The characteristics of participants are presented in Table 1. The Group I (n = 26) experimental group underwent SSGs with floaters training. Group II (n = 26) served as the control group. Before participating, each participant issued written informed consent. The university’s institutional ethical committee granted approval for the study (No.:HEC/PU/2023/03-07-2023).

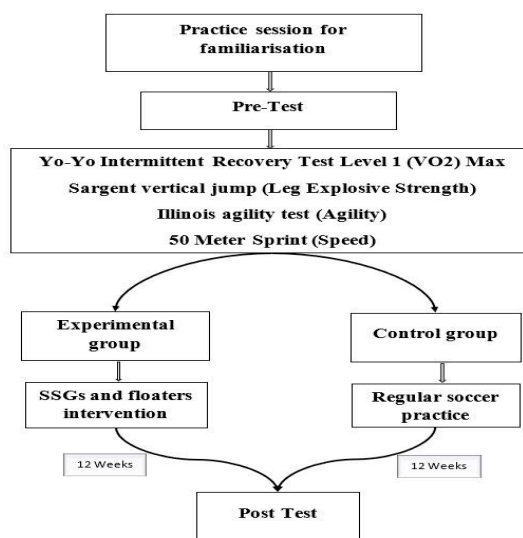


Fig. 1. Schematic diagram of the experimental protocol and variable measurements followed in experimental and control groups

Design

The SSGs with floaters training group underwent weekly training for five days (Monday, Tuesday, Wednesday, Friday, and Saturday). The practice session was only held in the morning session. Each session lasts 90 minutes and includes warm-up, SSGs with floaters training, match practice, and cooling-down exercises. The control group engaged in their

weekly schedule; they were on regular practice sessions. The training program lasted a total of 12 weeks. The pre-test measurements were taken one week prior to the beginning of the study. In order to facilitate the participant's familiarisation with the assessments, each test was administered twice prior to their conducting. All tests were performed on a soccer field. The assessments were administered again one week after (post-test) the completion of the training to evaluate the effect of the SSGs with floaters training.

Procedure

The training sessions and physical performance tests were conducted in the same environmental conditions, such as a soccer field. On the testing day, all participants completed the same eight-minute warm-up before the tests, including multi-directional lunges and bodyweight squats combined with mild running and dynamic stretches. After the warm-up, subjects were given two practice trials for each test. Consistent feedback was provided throughout to ensure proper technique. These tests were conducted in a single session. The participants were instructed to avoid any strenuous exercise for at least 24 hours before testing. Furthermore, players were advised to refrain from consuming caffeine or other stimulants that might affect their natural performance. They were also reminded of the importance of maintaining proper nutrition and optimal hydration 48 hours before the testing session. The participants performed vertical jump tests with barefoot and maximal aerobic endurance, sprint, and agility testing with soccer boots. The testing sessions consisted of the subsequent sequence of tests: Sargent jump test for leg's explosive strength, 50-meter sprint, Illinois agility test and Yo-Yo intermittent recovery test level 1 for Maximal aerobic endurance ($\text{VO}_{2\text{max}}$).

Yo-Yo Intermittent Recovery Test Level 1

The participants were required to perform 2×20 m shuttles. They started with both feet positioned behind the starting line and took breaks by walking to a cone located five meters behind the starting line. The test was controlled by an auditory signal that gradually increased in speed. The test started at a running speed of 10 km/h, increasing by 2 km/h in the next level and by 1 km/h in subsequent levels, with further increases of 0.5 km/h in each subsequent level. At least one foot had to contact the 20-meter line before changing direction and returning to the start point. After each run, there was a 10-second rest period during which participants covered a distance of 10 meters (2×5 meters) behind the starting line to prepare for the next repetition. This sequence continued until the participant could not maintain the required pace set by the auditory signal for two consecutive runs. Participants could either voluntarily quit the test or were eliminated if they failed to reach the finish line on time twice. During the test, a yellow card was issued the first time a participant failed to reach the line on time, and the test was terminated with a red card on the second occasion. The score recorded was the distance of the last completed shuttle, converted to meters by multiplying each completed level by 40. The $\text{VO}_{2\text{max}}$ could be estimated from the participant's performance in the test using the equation: $\text{VO}_2 \text{ max prediction (mL/kg/min)} = \text{Yo-Yo IR1 distance}$

(meters) $\times 0.0084 + 36.4$ recommended by (Bangsbo et al., 2008).

Vertical jump

The Sargent jump test was used to evaluate vertical jump performance as a measure of leg explosive strength. A tape measure was fixed to the wall for vertical jump measurement. The participants were standing sideways against a wall and stretching as high as possible with their fingertips. To perform the jump, participants began by standing upright and then lowered themselves into a knee-bent position to a depth of their choice, and they had to jump as high as possible, marking the wall using chalk. The vertical jump was determined based on the distance between the initial standing position and the mark created during the jump. During the execution of the jump, participants were required to maintain continuous movement throughout the descent and propulsive phases. Each subject underwent two assessments with a period of passive rest in between.

Illinois Agility Test

The starting and finishing points of the Illinois agility test are located in a 10-meter-long and 5-meter-wide rectangle. The start and finish points of the trail, as well as the two corners where competitors must turn, are marked with four cones. The testing area was set up with four cones, each spaced 3.3 meters apart. A stopwatch was used to measure the time. The test requires the participant to lie on their front with their hands resting on their shoulders and their head directed towards the start line. At the researchers' "Go" command, the stopwatch was started, and participants promptly stood up and sprinted 10 meters from the starting position to the first corner cone; participants had to touch or cross the tape mark with their feet. After turning around, they returned to the first centre cone and weaved back and forth through the four centre cones. Next, the participant should sprint as fast as possible to the second tape mark located on the far line, where they again needed to touch or cross the end-line tape marks with their foot. Finally, the participants quickly turned and sprinted across the finish line as quickly as possible without stepping on any of the cones. Each subject performed two trials with 2-minute rest intervals. The fastest time was measured in seconds.

50 Meter

The 50-meter sprint tests were performed to assess the maximum speed of the soccer players. The beginning and ending points were clearly indicated with cones. The sprint was timed using a stopwatch. The test was performed twice, with a recovery time of 6 minutes between trials. The individual should be motivated to avoid decelerating before reaching the finishing point. The fastest time from the two sprints was chosen for further statistical analysis. The scores were in seconds.

Statistical Analysis

Mean and standard deviation were calculated for all variables for descriptive statistics. The normality of the

examined parameters was assessed using the skewness and kurtosis test. Paired t-test was used to identify significant changes between the pre-test and post-test variables in both groups. Additionally, the effect of training was assessed using an analysis of covariance (ANCOVA) statistical model, in which baseline data were added as covariates. The size of the difference between the two groups was assessed by computing Cohen's d effect sizes. The interpretation of values was based on the recommendations of Hopkins et al. (2009), categorised as follows: < 0.20 was considered trivial, 0.20–0.60 as small, 0.61–1.20 as moderate, 1.21–2.0 as large, and > 2.0 as very large. The SPSS statistics 21 Packages were used to compute and evaluate all the data. The significance level was set at ≤ 0.05 level. SPSS Statistical package is used as a statistical tool.

Table 1. Characteristics of the participants

Participants	Control Group (M $\pm$ SD) (n = 26)	Experimental Group (M $\pm$ SD) (n = 26)
Age	15.60 $\pm$.68	15.40 $\pm$.59
Years of Experience	6.53 $\pm$ 1.99	6.43 $\pm$ 1.86
Height (cm)	160.70 $\pm$ 12.85	161.10 $\pm$ 12.08
Weight (Kg)	59.70 $\pm$ 3.9	60.10 $\pm$ 4.3

Table 2. The small-sided floaters training programme

Format	Size of Field (M) L x W	Regimen	Intensity
1 vs 1 + 2 Floaters	6 $\times$ 18	6 $\times$ 1 min/ 2 min rest	80 %
2 vs 2 + 2 Floaters	12 $\times$ 24	6 $\times$ 2 min/ 2 min rest	88 %
3 vs 3 + 2 Floaters	18 $\times$ 30	6 $\times$ 3 min/ 2 min rest	92 %
4 vs 4 + 4 Floaters	24 $\times$ 36	6 $\times$ 4 min/ 2 min rest	91 %
5 vs 5 + 3 Floaters	30 $\times$ 35	6 $\times$ 4 min/ 2 min rest	93 %
6 vs 6 + 4 Floaters	30 $\times$ 40	3 $\times$ 4 min/ 3 min rest	87 %
7 vs 7 + 5 Floaters	64 $\times$ 46	3 $\times$ 7 min/ 3 min rest	94 %
8 vs 8 + 1 Floater	70 $\times$ 45	4 $\times$ 8 min/ 1 min rest	88 %
9 vs 9 + 1 Floater	60 $\times$ 50	3 $\times$ 5 min/ 4 min rest	81 %

Results

Table 3 displays the summary of test results for both the control group and the experimental group. Pre-test comparisons across variables showed no significant

Table 3. Results summary for all tests performed in the control and experimental groups

Variable	Control Group				Experimental Group				F	ANCOVA, p (after intervention)
	Pre- Test	Post-test	p	Cohen's d	Pre-Test	Post-test	p	Cohen's d		
Maximal Aerobic endurance	43.17 $\pm$ 2.87	45.28 $\pm$ 3.07	.000*	1.01	41.99 $\pm$ 2.33	45.37 $\pm$ 2.88	0.000*	2.10	4.676	0.035*
Leg Explosive Strength	36.24 $\pm$ 6.20	36.85 $\pm$ 4.16	.603	0.11	37.01 $\pm$ 5.61	39.41 $\pm$ 3.60	0.001*	0.46	6.452	0.014*
Agility	18.70 $\pm$ 0.83	18.59 $\pm$ 0.68	.589	0.107	18.67 $\pm$ 0.98	18.36 $\pm$ 0.68	0.037*	0.43	5.64	0.021*
Speed	7.89 $\pm$ 0.51	7.72 $\pm$ 0.39	.074	0.365	7.77 $\pm$ 0.49	7.55 $\pm$ 0.53	0.001*	0.726	0.962	0.331

differences between groups at the baseline level. The paired t-test results for maximal aerobic endurance revealed a significant improvement between the pre-test and post-test for both the control and experimental groups ($p < 0.05$). The ANCOVA result further revealed a significant difference in maximal aerobic endurance between the control and experimental groups ($F = 4.676$, $p = 0.035$). Paired sample t-test result of leg explosive strength and agility revealed a significant improvement ($ES = 0.46$, $ES = 0.43$) for SSGs with floaters training group but no improvement in the control group ($p > 0.05$). The ANCOVA result showed that there is a significant difference between the control and experimental groups in leg explosive strength ($F = 6.452$, $p = 0.014$) and agility ($F = 5.64$, $p = 0.021$). The paired sample t-test results for speed indicated no significant improvement for both the control group and the experimental group. Additionally, the ANCOVA results revealed no significant difference in speed between the control and experimental groups ($F = 0.962$, $p = 0.331$).

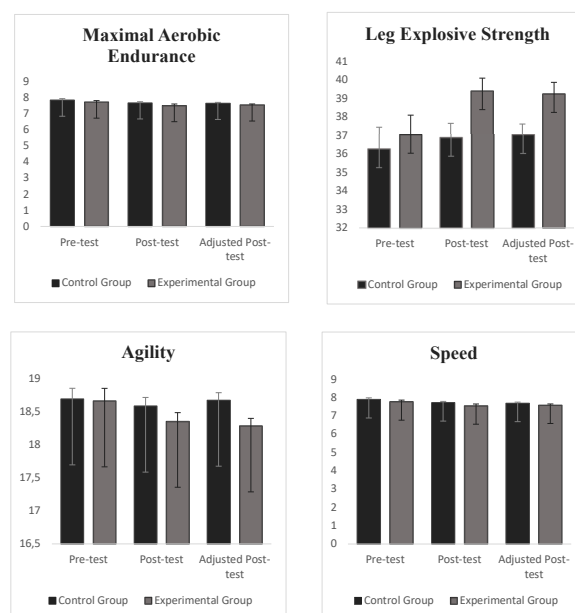


Fig. 2. Graphical presentation of the physical components in the experimental group and control group

Discussion

The primary objective of this study was to assess the effects of a 12-week training program involving SSGs with floaters training on the physical performance,

such as maximal aerobic endurance, leg explosive strength, agility, and speed of soccer players. Moreover, the study aims to determine whether the effects of a 12-week training program involving SSGs with floater interventions were more effective in improving physical performance compared to a control group.

The pre-and post-training results show that the experimental group, which underwent SSGs with floaters interventions, showed significant improvement in maximal aerobic endurance ($p < 0.0001$; $d = 2.10$). Our result is consistent with some of the previous studies stating that the use of a floater seems to be more effective in soccer games with a smaller size, and this could be suitable for the maintenance or development of aerobic capacity (Hill-Haas et al., 2010) and also regarding the team size, SSGs with fewer players appear to have a more significant effect on aerobic capacity (Pop et al., 2022). The control group also shows significant improvement in maximal aerobic endurance ($p < 0.0001$; $d = 1.01$). The control group showed a change in maximal aerobic endurance, likely due to their high-intensity daily training load (Table 3). This present study found a significant difference between the experimental and control groups. Compared to the control group, the experimental group showed greater maximal aerobic endurance; similarly, previous research has demonstrated a high increase in VO_{2max} ability in the small-sided games experimental group compared to the control group (Resah Pratama et al., 2024; Xu et al., 2024). Similarly, Rampinini et al. (2007) suggested that smaller-sided games induce higher physiological stress, resulting in superior cardiovascular adaptations compared to conventional endurance training. In contrast to our result, Thomakos et al. (2023) observed no significant improvement in aerobic fitness within an SSG group. This discrepancy could be attributed to differences in training intensity, duration, or tactical constraints imposed during sessions. Moreover, Aguiar et al. (2013) suggest that in SSGs, coaches can use fewer players, such as 2- and 3-a-side, to enhance cardiovascular effects. Conversely, using more players, like 4- or 5-a-side, can enhance variability and better align with the specific demands of competition. The studies corroborate that modifying the number of players and pitch dimensions directly influences training load, movement patterns, and aerobic responses (Owen et al., 2014; Dellal et al., 2012). The role of floaters in SSGs may provide a key differentiating factor by increasing overall game dynamics, movement variability, and positional play, leading to sustained high-intensity activity (Clemente et al., 2021; Castillo et al., 2018). However, these studies primarily focus on SSGs alone, without incorporating floater interventions, making this study a unique contribution to the field. Practically, integrating small-sided games with floaters can serve as an effective training strategy to enhance aerobic endurance. The inclusion of floaters provides tactical benefits, promoting increased ball possession, sustained movement intensity, and varied positional demands (Sánchez-Sánchez et al., 2018; Köklü et al., 2015). Coaches can optimize training by adjusting team formations, modifying pitch size, and managing the intensity of floater involvement to maximize physiological adaptations.

Analyzing the results in the explosive leg strength, our results suggest that SSGs with floaters intervention significantly improved leg explosive strength ($p < 0.01$;

$d = 0.46$). These improvements are in accordance with previous studies explaining that vertical jump performance was significantly enhanced with the implementation of SSGs in sedentary adults, irrespective of sex (Xu et al., 2024), and Karahan (2020) suggests that SSGs were found to be effective in improving the explosive power and vertical jump heights of young soccer players during the pre-season preparation period. Conversely, other research demonstrates that there was no change in muscle power after six weeks of SSGs (Ouertatani et al., 2022). While comparing the difference between the experimental and control groups, the result shows that the experimental group (SSGs with floaters training) exhibited higher leg explosive strength after 12 weeks.

Regarding agility, the results of this study suggest that the 12 weeks of SSGs with floaters intervention significantly improved agility ($p < 0.05$; $d = 0.43$) from pre- to post-training. Our result aligns with other researchers who have found that SSGs enhance agility performance by improving the speed of cognitive decision-making rather than physical movement speed (Young & Rogers, 2014). According to Chaouachi et al. (2014), the SSGs can be an effective approach to enhancing agility and change of direction in elite-level young male soccer players, they also recommend reducing the number of players to improve agility. This study also found a significant difference between the experimental and control groups; the experimental group showed greater agility than the control group. Similarly, Subramani & Arumugam (2015) reported that the SSGs training group showed significant improvement in agility compared to the control group. Additionally, Salazar-martínez et al. (2023) Top of FormBottom of Form found the same stated that compared to the high-intensity interval training group, the SSGs experimental group showed better agility time. However, Karahan (2020) reported that practising skill-based training with maximum intensity might be more useful than small-sided games in enhancing the physical performance variables of young football players during the pre-competitive season. Nonetheless, these studies do not adequately address interventions involving floaters.

Considering the speed, there is no improvement in SSGs with floaters intervention experimental group and control group. Our findings align with the works of Hill-Haas et al. (2009) and Radziminski et al. (2013), who reported that no significant change in speed performance after the SSGs intervention. As Nayiroğlu et al. (2022) noted, this result is anticipated in SSGs because there is often acceleration and deceleration, mainly caused by the reduced dimensions of the playing field and other limitations imposed by the drills. However, a four-week small-sided games training program resulted in a significant enhancement in repeated sprint ability, as evidenced by the decrease in the time taken to complete a 10-meter sprint (Owen et al., 2012). The result regarding speed also shows that there is no significant difference between the experimental and control groups. A similar result was reported by Karahan (2020), indicating that skill-based training helps to improve 20-meter sprint performance in soccer players compared to SSGs. Chaouachi et al. (2014) also found that the control group significantly improved in sprinting longer than 10 meters, and they recommend that this may be possible due to the potential impact of soccer training on short-term anaerobic

fitness. The lack of significant improvements in speed among soccer players in this study could be attributed to the limited training period and the starting level of physical fitness of players.

This study has certain limitations. The main limitation of this study was the small sample size, which limited the generalisations. Hence, it is important to interpret conclusions carefully. Additionally, another limitation of this study was absence of a specific small-sided games group (SSGs without floaters). Another major constraint of the study could be attributed to the fluctuation in climatic circumstances throughout the intervention period, which may have led to varied results. However, this is the first study to analyse a 12-weeks intervention involving SSGs with floaters intervention on the physical performance of soccer players. Furthermore, future investigations should focus on including players from various age groups and skill levels. They should also examine the differences in technical-tactical actions related to the manipulation of floaters' positioning.

Conclusion

The aim of this study was to evaluate the effect of SSGs with floaters intervention on the physical performance of junior soccer players. The findings suggest that SSGs with floaters training significantly improve physical performance variables, including maximal aerobic endurance, leg explosive strength, and agility. However, this specific training did not make any improvements in speed. There is a significant difference between the experimental and control groups in maximal aerobic endurance, leg explosive strength, and agility except for speed, and the experimental group showed significant improvement compared to the control group. The SSGs format, when combined with floaters, is well-suited for soccer training due to the number of opportunities it provides for players to deal with competitive game situations, including numerical imbalances in both attack and defense. Attention should be given to applying SSGs with floaters intervention methods to improve physical performance, incorporating more advanced training concepts to increase training efficiency and effectiveness, thereby enhancing athletic performance. This study highlights the need for further exploration into optimized training methods tailored for young soccer players.

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Conflicts of Interest

There are no conflicts to declare.

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Вплив ігор неповними складами та інтервенції із застосуванням позиції флоатерів на показники фізичних компонентів футболістів

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

Реферат. Стаття: 9 с., 3 табл., 2 рис., 47 джерел.

Історія питання. Чисельна перевага у футболі підвищує ефективність як атакуючих, так і захисних дій, що виконуються гравцями. Щоб поліпшити результативність гравців, слід включати у тренувальні заняття ігри неповними складами (SSGs) із чисельною меншістю та перевагою.

Мета дослідження. Мета дослідження полягала в оцінюванні впливу 12-тижневої програми тренування із застосуванням позиції флоатерів та ігор неповними складами (SSGs) на фізичну працездатність футболістів.

Матеріали та методи. У дослідженні взяли участь 52 футболісти. Вік гравців коливався від 14 до 16 років. Учасників було розподілено на групу І із проведенням ігор неповними складами із застосуванням позиції флоатерів (група І, SSGs+Floaters, n = 26) та контрольну групу (група ІІ, n = 26). Експериментальна група пройшла 12-тижневу програму із впровадження ігор неповними складами, що передбачала проведення інтервенції із застосуванням позиції флоатерів, тренуючись п'ять днів на тиждень. Кожне заняття тривало 90 хвилин і включало в себе розминку, ігри неповними складами із проведенням інтервенції, що передбачала застосування позиції флоатерів, підвідні ігри та приведення організму до нормального стану після тренування. У контрольній групі програма тренувань із застосуванням позиції флоатерів не практикувалася. З метою оцінки максимальної аеробної витривалості (VO_{2max}) використовувався тест Йо-Йо з переривчастим відновленням рівня 1, для вимірювання вибухової сили ніг — стрибковий тест Сарджента (вертикальний стрибок), для оцінки футбольної спритності — Іллінойський тест на спритність, а для оцінки швидкості — спринтерський тест на дистанцію 50 метрів. Для вимірювання внутрішньогрупових відмінностей показників на етапах перед та після завершення тестування було проведено тест із застосуванням t-критерію для парних вибірок, а вплив тренувань оцінювали за допомогою коваріаційного аналізу (ANCOVA) та аналізу розміру ефекту.

Результати. Результати дослідження показали, що ігри неповними складами із проведенням інтервенції, яка передбачала застосування позиції флоатерів, сприяли значному покращенню показників максимальної аеробної витривалості, вибухової сили ніг та спритності, за винятком швидкості. Натомість контрольна група не продемонструвала подібних позитивних змін. Крім того, між експериментальною та контрольною групами спостерігалася суттєва різниця у показниках максимальної аеробної витривалості, вибухової сили ніг та спритності, проте щодо швидкості такої відмінності не встановлено.

Висновки. Отримані дані свідчать про те, що впровадження ігор неповними складами та інтервенції із застосуванням позиції флоатерів сприяє ефективному підвищенню показників фізичної працездатності юних футболістів.

Ключові слова: ігри неповними складами, тренування флоатерів, VO_{2max} , спритність, вибухова сила ніг, швидкість.

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Defining the Effects of Floaters' Number on Internal Load, External Load and Technical Skills in Small-Sided Soccer Games

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Abstract

Objectives. This study aimed to examine the effects of different floater configurations in small-sided games (SSGs) on physiological responses, external load metrics, and technical performance among professional soccer players.

Materials and methods. Twenty male players from the Thailand League 3 (age: 21.4 ± 1.82 years) participated in three SSG formats: standard (4v4), one floater (4v4+1), and two floaters (4v4+2). Each format consisted of 4 × 4-minute bouts with 4-minute rest intervals on a 32 × 25-meter pitch. Heart rate responses, locomotor activities, and technical actions were analyzed.

Results. Significant reductions in maximal heart rate and mean heart rate were observed (181.55 vs 169.55 and 168.15 vs 156.15 beats·min⁻¹) in the 4v4+2 format compared to 4v4. High-intensity running decreased (238.60 vs 91.35 m), while technical performance improved, as evidenced by increased total passes and successful passes (81.25 vs 142.50 and 68.00 vs 123.00) in the 4v4+2 format. The 4v4+1 format provided intermediate responses in both physiological and technical parameters.

Conclusions. These findings suggest that floater-modified SSGs effectively reduce physiological demands while enhancing technical performance, offering coaches practical tools for manipulating training intensity and technical development in soccer training programs.

Keywords: small-sided games, heart rate, locomotor activities, technical skills, floater player.

Introduction

The evolution of soccer training methodologies has witnessed a paradigm shift with the emergence of small-sided games (SSGs) as a sophisticated training tool. While traditional training methods often separate physical conditioning from technical skill development, SSGs offer a unique solution by simultaneously addressing multiple performance components. Of particular interest is the innovative use of floaters – additional players who participate for the possession team – which has emerged as a compelling variable in training design, yet remains insufficiently understood in terms of its comprehensive impact on player performance (Clemente et al., 2021). Recent meta-analytical findings have revealed intriguing relationships between SSG design variables and performance outcomes.

Clemente et al. (2023) discovered substantial effect sizes for pitch size modifications on physiological responses, physical demands, and technical actions. These compelling results suggest that spatial constraints significantly influence training outcomes, raising important questions about how the addition of floaters might modulate these effects. Most soccer training consists of internal loads consisting of heart rate zones and measurements derived from heart rate, including the level of perceived exertion (SRPE). External loads consist of distance in different speed zones, total distance, and acceleration (Sobolewski, 2020).

The manipulation of floater numbers presents a fascinating paradox in training design. Asian-Clemente et al. (2021) revealed that incorporating two floaters led to counterintuitive results: significant reductions in total distance (-12.3%), high-speed running (-18.7%), and accelerations (-15.4%). This unexpected finding challenges conventional wisdom about numerical advantages in soccer and suggests a more complex relationship between player numbers and physical demands than previously assumed. Contemporary professional soccer demands have reached unprecedented

levels, with Gualtieri et al. (2023) documenting that elite players must perform 55-75 high-speed running actions and 15-35 sprints per match. The challenge of replicating these demands in training while maintaining technical quality has become a central concern for practitioners. Remarkably, Riboli et al. (2023) demonstrated that manipulating area per player (75-175 m²) could explain 56% of the variance in high-speed running distances ($\eta^2 = 0.56$) and 48% of sprint distances ($\eta^2 = 0.48$), suggesting a powerful tool for load management. A particularly compelling finding emerges from the work of Nunes et al. (2020), who discovered that numerical superiority created by floaters produced a fascinating cascade of effects: reduced physiological stress (-8.5% heart rate, -25.3% blood lactate) coupled with enhanced technical performance (+35.7% possession duration, +42.3% successful passes). This intricate relationship between physical relief and technical enhancement offers exciting possibilities for optimizing training design. The quest for optimal training parameters has yielded surprising insights. Riboli et al. (2020) identified a strong correlation between area per player and successful technical actions ($r = 0.78$, $p < 0.001$), suggesting that spatial constraints might be more crucial for skill development than previously recognized. This finding was further nuanced by their subsequent research with youth players (Riboli et al., 2022), revealing age-specific adaptations in spatial requirements.

Perhaps most intriguingly, de Dios-Álvarez et al. (2024) recently uncovered remarkably strong relationships between playing area and various performance metrics in elite youth soccer: total distance ($r = 0.85$), high-speed running ($r = 0.79$), and sprint distance ($r = 0.72$). These robust correlations suggest a level of predictability in training responses that could revolutionize SSG design. The temporal demands of modern soccer add another layer of complexity to this puzzle. Oliva-Lozano et al. (2021) identified that the most demanding passages of play exhibit 15-25% higher physical outputs than match averages, lasting 3-5 minutes. This finding raises crucial questions about how floater numbers might be manipulated to replicate or moderate these intense periods effectively. Despite these advances, a significant gap exists in our understanding of how floater numbers simultaneously influence internal load, external load, and technical performance. While individual relationships have been explored, the interaction effects remain largely unknown. This knowledge gap is particularly relevant given Dolci et al.'s (2020) documentation of increasing match demands, with elite players now covering 10-12 km and performing 150-250 high-intensity actions per match. This review aims to unravel the complex relationships between floater numbers and various performance parameters in soccer SSGs. By synthesizing current evidence and identifying methodological gaps, we seek to advance understanding of this crucial training variable. The findings hold significant implications for training optimization in modern soccer, potentially revolutionizing how we approach SSG design and implementation.

Based on these considerations, this research aims to investigate how small-sided games incorporating either one or two floaters influence physiological responses (heart rate), locomotor activities, and technical skill execution when implemented in soccer training. Specifically, this study examines whether different floater configurations (one versus

two floaters) result in significantly different proportions of cardiovascular response, movement patterns, and technical skill utilization among soccer players. The findings from this investigation will provide evidence-based guidelines for coaches to effectively implement small-sided games in training programs, optimizing both physical conditioning and technical skill development in soccer players.

Materials and Methods

Study Participants

The participants consisted of 20 male professional soccer players in Thailand League 3 (Age: 21.4 ± 1.82 years, Height: 175 ± 5.41 cm, Weight: 64.7 ± 3.87 kg, BMI: 21.1 ± 1.40 , Body fat percentage: 9.54 ± 3.30 , $\text{VO}_{2\text{max}}$: 57.7 ± 4.43 mL·kg⁻¹·min⁻¹). All participants underwent the Yo-Yo Intermittent Recovery Test Level 1 (YYIR1) to determine their maximal oxygen consumption. The $\text{VO}_{2\text{max}}$ was calculated using the formula: $\text{VO}_{2\text{max}}$ (mL·kg⁻¹·min⁻¹) = IR1 distance (m) $\times$ 0.0084 + 36.4 (Kabdwai et al., 2023). Participants were then randomly assigned to groups with no significant differences in mean $\text{VO}_{2\text{max}}$ values between groups. The inclusion criteria required participants to be free from any muscular or joint injuries and maintain regular training sessions for at least 5 days per week and 1 match per week. Exclusion criteria included a player having injuries that prevented participation in the experimental procedures, and non-compliance with research protocols. All participants were informed about the research procedures, potential benefits, and risks. Written informed consent was obtained from all participants. This study was approved by the Human Research Ethics Committee of Kasem Bundit University, Bangkok, Thailand, in accordance with the Declaration of Helsinki (approval number: KBU-HREC 034/67).

Study Organization

The small-sided games training with a small pitch format refers to a possession-focused training method conducted on a 32 $\times$ 25-meter pitch (1 player per 100 square meters) (Michailidis, 2024). Players were divided into two teams of 4 players each. The training consisted of 4 $\times$ 4-minute periods with 4-minute rest intervals between rounds (Riboli et al., 2023; Eniseler et al., 2017). A total of 4 sets were completed with free-play conditions and coach encouragement (Sarmiento et al., 2018). In the format with a neutral player, this player could only participate with the team in possession of the ball or in attacking play and was not allowed to challenge for the ball when possession was lost, as shown in Figure 1.

Before beginning the small-sided games training, participants completed a 15-minute warm-up protocol consisting of 5 minutes of jogging, 8 minutes of dynamic stretching exercises, and 3 repetitions of 10-meter maximum sprint runs for muscle activation (Eniseler et al., 2017).

Heart rate measurements were taken during resting conditions before each training session. A sample group of 20 participants was monitored, and training was suspended if heart rates exceeded normal parameters. Heart rate measurements were recorded during each small-sided game session. Heart rate monitoring was conducted using

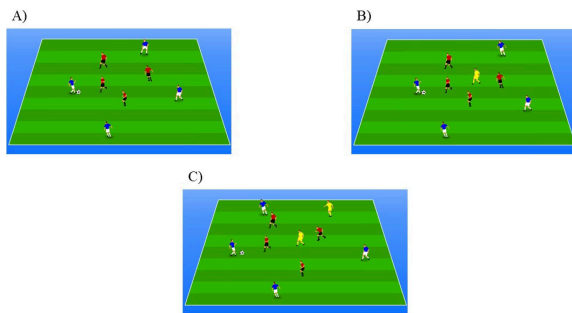


Fig. 1. Three SSG methods: (A) Ball possession without floater players; (B) Ball possession with 1 floater players; and (C) Ball possession with 1 floater

Polar Team Pro system (Polar Electro, Kempele, Finland) to determine internal and external loads for each player (McFadden et al., 2020). Individual participants' mean heart rates were categorized according to playing time proportion (%) using predetermined intensity zones: Zone 3: 70-79% HRmax, Zone 4: 80-89% HRmax, Zone 5: 90-100% HRmax. Maximum and average heart rate responses were recorded for each individual (Nagy et al., 2020). Locomotor activities during each small-sided game, the following parameters were measured: Total distance (TD), High-intensity runs (15-23.9 km/h), Sprint (>24 km/h) (Riboli et al., 2020). All training results were recorded during each session. The small-sided games were conducted between 4:00 - 6:00 PM. A minimum recovery period of 72 hours was implemented between training sessions before beginning a new SSG format (Silva et al., 2018; Goulart et al., 2022). During all small-sided games (SSG), video recordings were captured using a Veo

Sport Camera (Veo Technologies ApS, Denmark) positioned at a height of 5 meters above the center of the soccer field to ensure complete coverage of the playing area. To track the skills used by soccer players during small-sided games, the recorded videos were analyzed using Dartfish Live computer software (Dartfish, Fribourg, Switzerland) (Hintermann et al., 2021). The analyzed skills included: Total passes, Successful passes, Dribbling, and Interceptions (Riboli et al., 2023).

Statistical Analysis

Descriptive statistics were calculated for all experimental data as mean and standard deviation (SD). Normality of the distribution for all data was confirmed by Shapiro-Wilks test ($p > .05$). Differences between the performance outcome (Heart rate, Locomotor activities and Technical skills) were compared using one-way ANOVA was used to determine differences between Heart rate, Locomotor activities and Technical skills, with Bonferroni Post Hoc tests used to identify specific differences. Statistical significance was tested at $p < 0.05$, by SPSS Statistics Version 26 (IBM, Armonk, NY, USA).

Results

The finding of Internal and external loads values of the soccer players participating in the study after SSG with 4v4, 4v4+1, 4v4+2 are listed in Table 1.

Data on the internal and external loads during different SSGs formats (Table.1) showed that HR max, %HR max, HR mean, %HRmean, Zone3, Zone4, Zone5, Total distance, High-intensity runs SSGs 4v4 were higher ($p < 0.05$) than for SSGs

Table 1. Internal and external loads during different SSGs formats

Internal and external loads variables	Small-Sided Game Formats (n=20)		
	4v4	4v4+1	4v4+2
HR max (beats·min ⁻¹)	181.55 ± 8.75	175.65 ± 11.36	169.55 ± 8.85*
HR max (%)	90.70 ± 4.11	88.15 ± 5.65	85.00 ± 4.47*
HR mean (beats·min ⁻¹)	168.15 ± 10.09	165.95 ± 7.16	156.15 ± 11.73*
HR mean (%)	84.25 ± 5.13	83.25 ± 3.56	78.40 ± 5.72*
Zone 3	22.75 ± 13.10	15.80 ± 6.09	11.27 ± 5.43*
Zone 4	39.62 ± 11.77	47.20 ± 13.6	49.00 ± 8.70*
Zone 5	15.98 ± 12.12	15.16 ± 17.29	7.16 ± 10.23*
Total distance (m)	2596.25 ± 117.33	2584.60 ± 177.04	2475.25 ± 121.98*
High-intensity runs (m)	238.60 ± 82.72	158.80 ± 44.20 #	91.35 ± 35.91*
Sprint (m)	4.90 ± 4.21	4.90 ± 6.66	3.60 ± 8.79

* Significant difference ($p < 0.05$) between 4v4 and 4v4+2, # Significant difference ($p < 0.05$) between 4v4 and 4v4+1

Table. 2. Technical skills performance during different ssgs formats

Technical Skills Variables	Small-Sided Game Formats (n = 20)		
	4v4	4v4+1	4v4+2
Total passes	81.25 ± 15.39	105.75 ± 7.32#	142.50 ± 18.66*
Successful passes	68.00 ± 12.78	92.50 ± 6.85	123.00 ± 18.12*
Dribbling	11.25 ± 5.73	6.25 ± 2.50	6.00 ± 3.16
Interceptions	10.25 ± 3.40	12.00 ± 1.82	14.25 ± 2.50

* Significant difference ($p < 0.05$) between 4v4 and 4v4+2, # Significant difference ($p < 0.05$) between 4v4+1 and 4v4+2

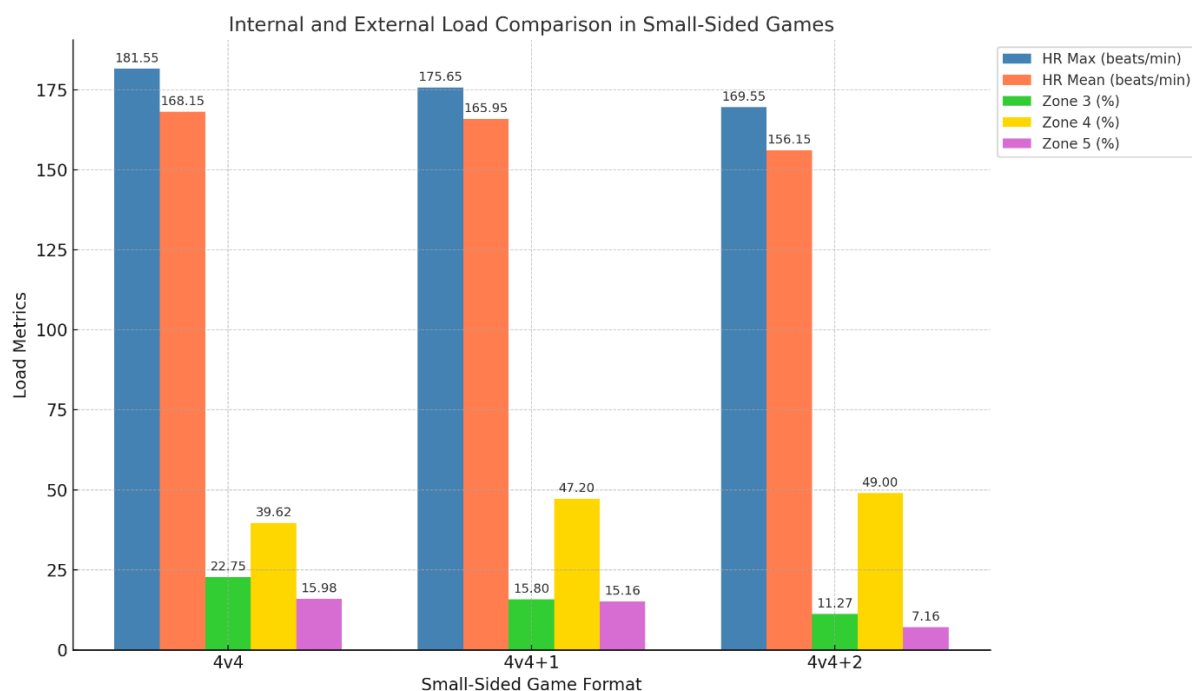


Fig. 2. Internal and external load comparison in small-sided games

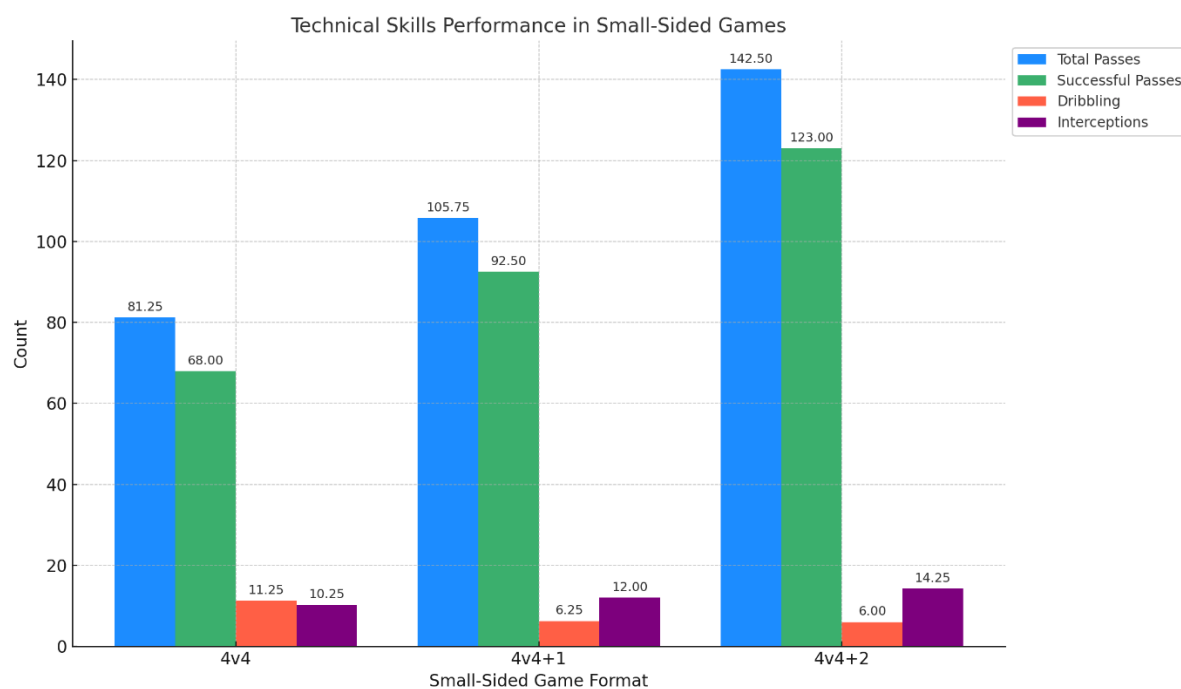


Fig. 3. Technical skills performance in small-sided games

4v4+2 (HR max: 181.55 ± 8.75 vs 169.55 ± 8.85 beats·min⁻¹, %HR max: 90.7 ± 4.11 vs 85.0 ± 4.47 %, HR mean: 168.15 ± 10.09 vs 156.15 ± 11.73 beats·min⁻¹, %HR mean: 84.25 ± 5.13 vs 78.40 ± 5.72 %, Zone 3: 22.75 ± 13.10 vs 11.27 ± 5.43 %, Zone 4: 39.62 ± 11.77 vs 49.0 ± 8.70 %, Zone 5: 15.98 ± 12.12 vs 7.16 ± 10.23 %, Total distance: 2596.25 ± 117.33 vs 2475.25 ± 121.98 m, High-intensity runs: 238.60 ± 82.72 vs 91.35 ± 35.91 m., respectively). And high-intensity runs SSGs 4v4 were higher ($p < 0.05$) than for SSGs 4v4+2

(High-intensity runs: 238.60 ± 82.72 vs 158.80 ± 44.20 m); however, there was no discernable difference between sprints in the small-sided games all the groups.

Data on the technical skills during different SSGs formats (Table.2) showed that total passes and successful passes SSGs 4v4+2 were higher ($p < 0.05$) than for SSGs 4v4 (total passes: 142.50 ± 18.66 vs 81.25 ± 15.39 pass, successful passes: 123.00 ± 18.12 vs 68.00 ± 12.78 pass) and total passes SSGs 4v4+1 were higher ($p < 0.05$) than for SSGs 4v4

(total passes: 105.75 ± 7.32 vs 81.25 ± 15.39 pass); however, there was no discernable difference between dribbling and interceptions in the small-sided games all the groups.

Discussion

This study investigated the effects of different floater configurations in small-sided games (SSGs) on internal load, external load, and technical performance among professional soccer players. The findings reveal significant differences across various performance parameters when comparing different SSG formats (4v4, 4v4+1, and 4v4+2), which warrant detailed discussion.

The results demonstrated significant reductions in cardiovascular demands when additional floaters were introduced, particularly in the 4v4+2 format compared to the standard 4v4 setup. The decrease in HRmax (181.55 ± 8.75 vs 169.55 ± 8.85 beats·min⁻¹) and HRmean (168.15 ± 10.09 vs 156.15 ± 11.73 beats·min⁻¹) represents approximately a 6.6% and 7.1% reduction respectively. This physiological response pattern aligns with recent research by Gantois et al. (2023), who found that manipulating SSG configurations significantly affects heart rate responses and perceived exertion. The magnitude of these changes is particularly noteworthy when compared to Rabano-Muñoz et al. (2023) findings, which reported similar reductions (5-8%) in internal load metrics among young elite players during defensive SSGs with numerical imbalances. The distribution of time spent in different heart rate zones revealed a systematic shift towards lower intensity zones with the addition of floaters. Zone 3 (70-79% HRmax) showed a marked decrease from $22.75 \pm 13.10\%$ in 4v4 to $11.27 \pm 5.43\%$ in 4v4+2, while Zone 4 (80-89% HRmax) increased from $39.62 \pm 11.77\%$ to $49.0 \pm 8.70\%$. This redistribution suggests a more controlled physiological response, supporting Guard et al. (2022) conclusions about the effectiveness of numerical imbalance in modeling training intensity while maintaining tactical engagement. Meanwhile, Ueda et al. (2023) conducted a study comparing 3v3 and 6v6 minigames and found that smaller formats create an environment in which players display more aggressive behavior, with more movement towards the opponent's goal and more frequent duel. This can be explained by reduced opportunities to play together, and the need to develop individual skills to deal with different game situations. This study highlights that managing numerical ratios between teams in small-sided games influences decision-making and strategic aspects. An increased number of opponents leads to lower heart rates, reduced uncertainty, and reduced flexibility, resulting in different internal loads, which is consistent with the results of this study.

The analysis of external load metrics revealed substantial differences between SSG formats, particularly in high-intensity activities. The 4v4+2 format resulted in a 4.7% reduction in total distance covered (2596.25 ± 117.33 m vs 2475.25 ± 121.98 m) compared to the 4v4 format. More dramatically, high-intensity runs decreased by 61.7% (238.60 ± 82.72 m vs 91.35 ± 35.91 m), indicating a fundamental shift in movement patterns. These findings expand upon Asian-Clemente et al. (2021) research on high-speed training adequacy in SSGs, demonstrating that while floater-modified formats may reduce high-intensity actions,

they maintain sufficient overall physical engagement for training purposes. Trombiero et al. (2023) research on numerical superiority provides context for these changes, suggesting that the reduced physical demands stem from improved tactical positioning and ball circulation. This is further supported by our sprint distance data, which showed no significant differences between formats (4.9 ± 4.21 m vs 3.6 ± 8.79 m), indicating that while sustained high-intensity running decreased, the opportunity for explosive actions remained consistent.

The technical analysis revealed substantial improvements in passing metrics with the addition of floaters. The 4v4+2 format demonstrated a 75.4% increase in total passes (142.50 ± 18.66 vs 81.25 ± 15.39) and an 80.9% increase in successful passes (123.00 ± 18.12 vs 68.00 ± 12.78) compared to the 4v4 format. The success rate of passes also improved from 83.7% in 4v4 to 86.3% in 4v4+2, indicating enhanced technical efficiency. These improvements align with Clemente and Sarmiento's (2020) systematic review findings on SSG effects on technical actions. Notably, while passing metrics improved significantly, dribbling frequency decreased from 11.25 ± 5.73 in 4v4 to 6.00 ± 3.16 in 4v4+2, suggesting a shift towards more collaborative play patterns. This aligns with Ueda et al. (2023) research on creative movements in SSGs, indicating that numerical advantages promote collective tactical solutions over individual actions. The enhanced passing performance observed in our study reflects both technical and cognitive adaptations. The increase in successful passes (80.9%) coupled with a higher success rate suggests improved decision-making under reduced temporal pressure. Sousa et al. (2021) demonstrated that unbalanced formats affect decision-making processes by creating clear numerical advantages, allowing players more time and options for tactical choices. The relationship between technical execution and tactical positioning is further evidenced by the increase in interceptions (10.25 ± 3.40 to 14.25 ± 2.50) in the 4v4+2 format. This improvement, as supported by Coutinho et al. (2024) research on ball possession directionality, suggests that players in the defensive phase adapted their positioning to compensate for the numerical disadvantage. These findings provide specific guidelines for training design in professional soccer. The observed 6.6% reduction in HRmax and 61.7% reduction in high-intensity running with 4v4+2 formats suggests these configurations are ideal for technical development sessions or recovery training. This aligns with Nagy et al.'s (2020) findings that different SSG formats can be strategically employed to achieve specific training objectives, with larger-sided games (including floaters) being particularly effective for technical development while maintaining moderate physiological demands. Their research demonstrated that manipulating player numbers is an effective tool for controlling training intensity, with formats similar to our 4v4+2 configuration producing lower physiological responses while maintaining high levels of technical engagement. However, as highlighted by Rabano-Muñoz et al. (2023), coaches should consider complementary high-intensity training to maintain match-specific physical capabilities. The progressive changes observed from 4v4 to 4v4+1 to 4v4+2 formats provide coaches with a systematic approach to manipulating training intensity. The intermediate responses in the 4v4+1 format (e.g., 158.80 ± 44.20 m high-intensity running) offer a

stepped approach to load management while maintaining technical engagement. An increase in the number of teammates produced an increase in the frequency of attacking patterns. By contrast, an increase in the number of opponents produced a decrease in the use of basic actions such as passing or driving by players in possession of the ball, while an increase in the number of teammates produced more defensive actions focused on protecting the goal, with more players balancing, although it did not produce an increase in the number of players pressing or dissuading. (Torrents et al., 2019)

Future research should investigate the long-term training adaptations to different SSG formats with varying floater numbers and examine how these adaptations might differ across playing levels and positions. Additionally, morphometric indicators and the role of soccer players should also be taken into account, particularly in light of recent work by Coutinho et al. (2024) on the impact of spatial constraints on player behavior.

Conclusions

This study demonstrates distinctive performance characteristics between standard small-sided games (4v4) and formats incorporating floaters (4v4+1, 4v4+2), providing valuable insights for training application in professional soccer. In standard 4v4 formats, players exhibited higher physiological responses and increased high-intensity running (238.60 ± 82.72 m), making this format particularly effective for high-intensity interval training and match-specific conditioning. These characteristics align with professional match demands, as documented by Gualtieri et al. (2023), who identified the need for 55-75 high-speed running actions per match.

Conversely, floater-modified formats demonstrated distinct advantages for technical development. The 4v4+2 configuration significantly enhanced passing while reducing physiological stress. This format proves particularly valuable for technical training sessions, recovery days, or tactical development. The intermediate 4v4+1 format offers a balanced approach, maintaining moderate physiological demands while facilitating improved technical execution. This configuration provides coaches with a flexible tool for progressive training adaptation and can be particularly useful during transitional training phases.

In conclusion, floater-modified SSGs represent an effective training tool that simultaneously addresses multiple performance components in soccer training. The evidence supports their strategic implementation while highlighting the importance of systematic training design based on specific developmental objectives.

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Conflict of Interest

The authors declare no conflict of interest.

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Визначення впливу кількості флоатерів на внутрішнє навантаження, зовнішнє навантаження та технічні навички в іграх неповними складами

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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 табл., 2 рис., 35 джерел.

Мета дослідження. Це дослідження мало на меті вивчити вплив різних конфігурацій флоатерів у іграх неповними складами (SSGs) на фізіологічні реакції, показники зовнішнього навантаження та технічну результативність серед професійних футболістів.

Матеріали та методи. Двадцять гравців чоловічої статі з Таїландської 3-ї ліги (вік: $21,4 \pm 1,82$ року) брали участь у трьох форматах ігор неповними складами: стандартному (4v4), із залученням одного флоатера (4v4+1) та з двома флоатерами (4v4+2). Кожен формат складався з 4 × 4-хвилинних поєдинків з 4-хвилинними інтервалами відпочинку, які проводилися на майданчику розміром 32 × 25 метрів. Проаналізовано реакції серцевого ритму, локомоторну активність та технічні дії.

Результати. У форматі 4v4+2 спостерігалось значне зниження максимальної та середньої частоти серцевих скорочень порівняно з 4v4 (181,55 проти 169,55 та 168,15 проти 156,15 уд·хв⁻¹). Показники високоінтенсивного бігу зменшилися (238,60 проти 91,35 м), тоді як рівень технічної результативності покращився, про що свідчить збільшення загальної кількості пасів та успішних передач (81,25 проти 142,50 та 68,00 проти 123,00) у форматі 4v4+2. Формат 4v4+1 показав проміжні результати як за фізіологічними, так і за технічними параметрами.

Висновки. Отримані дані дозволяють припустити, що модифіковані ігри неповними складами із застосуванням позиції флоатерів сприяють ефективному зниженню фізіологічних вимог та водночас підвищують технічну результативність, надаючи тренерам практичні інструменти для маніпулювання інтенсивністю тренувань і технічного розвитку в тренувальних програмах з футболу.

Ключові слова: ігри неповними складами, частота серцевих скорочень, локомоторна активність, технічні навички, гравець-флоатер.

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Considering the Impact of a 12-Week Intervention Program on Behavioral Intentions and Key Health-Related Constructs in Adolescent Basketball Players

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Abstract

Objectives. This study aimed to evaluate the impact of a 12-week basketball intervention program on adolescents' behavioral intentions and key health-related constructs, including self-efficacy, social support, situational factors, and outcome expectations, based on the social cognitive theory (SCT), focusing on each gender and comparing both genders.

Materials and methods. A total of 175 adolescents (age: 12–14 years old) from basketball clubs in Guangxi Province, China, were involved in the study. The participants were divided by gender into two groups (male [$n = 88$] and female [$n = 87$] groups) and underwent an intervention program for 12 weeks. The validity and reliability of all measurements were tested. Regression analysis was used to identify predictors of behavioral intentions, which were used to design the intervention program.

Results. The intervention significantly improved self-efficacy, social support, situational factors, outcome expectations, and behavioral intentions in both male and female adolescents. Behavioral intentions score increased from 3.19 to 3.77 for male adolescents and from 3.3 to 4.27 for female adolescents ($p < 0.001$). Furthermore, it was noted an increase in self-efficacy scores from 3.51 to 4.22 for male adolescents and from 3.26 to 4.23 for female adolescents ($p < 0.001$). Improvements in other constructs were also observed in both genders, with no significant gender differences in post-intervention outcomes ($p > 0.05$).

Conclusions. The findings indicate that a 12-week intervention program based on the SCT effectively enhanced adolescents' behavioral intentions and related constructs. Developing gender-specific intervention programs is important for maximizing intervention effectiveness.

Keywords: behavioral intentions, basketball training, self-efficacy, social support, situation, outcome expectations.

Introduction

The participation in sports has a positive impact on the mental health and subjective well-being of school-aged children and adolescents, particularly regular physical activities that enhance emotional regulation and social support (Liu et al., 2022). However, many adolescents fail to meet recommended levels of physical activity (PA) due to academic pressures and developmental complexities (Guthold et al., 2020). Participation in youth sports positively impacts children's health and well-being; however, barriers such as limited resources and lack of familial support often hinder full participation in sports activities (Kuhn et al.,

2021). Social Cognitive Theory (SCT) provides a robust framework for understanding and predicting adolescents' sports participation (Bandura, 1997). The social cognitive theory model can moderately predict adolescent physical activity; self-efficacy, barrier self-efficacy, social support, and social status are key indicators for predicting physical activity (Liu et al., 2020).

Gender differences are prevalent in the field of mental health, particularly among adolescents, with females generally experiencing higher levels of psychological distress and lower life satisfaction. However, this gender gap exhibits significant heterogeneity across different countries and cultural contexts (Campbell, Bann, & Patalay, 2021). Gender differences significantly impact sports participation, and challenges in training time and support mechanisms disproportionately affect girls (Fredricks & Eccles, 2006). In particular, PST

interventions that focus on self-efficacy and observational learning have been shown to promote PA participation (Islam et al., 2023). Technology-based solutions, such as mobile apps, have proven effective in delivering flexible and engaging PST interventions (Wekesser et al., 2021). However, psychological research on sports and exercise continues to exhibit a significant gender imbalance, and male participants are overrepresented, particularly in experimental studies in Europe (Walton et al., 2022). Therefore, more inclusive and representative approaches are required in future research.

Gender-sensitive approaches are essential, as societal and structural factors shape girls' participation in PA. Peer and family support, along with individual and social motives like enjoyment and achievement, sustain engagement in sports (Wang, 2024). Additionally, the quality of coaching and adequate facilities are critical factors for sustaining participation. SCT-based educational interventions enhance PA levels among female students in high school by improving self-efficacy, family support, and self-regulation (Hashemian et al., 2021). Similarly, SCT is widely used in strength training programs, particularly those led by exercise specialists in community settings (Ma et al., 2022). Physical performance in basketball is also influenced by individual characteristics. Gender-sensitive approaches are essential, as societal and structural factors significantly impact girls' participation in PA. Peer and family support are crucial for sustained engagement (Schlund et al., 2021; Zhang et al., 2022; Sheikh et al., 2022). Leaner adolescent basketball players tend to perform better because body size and individual characteristics play a more significant role than training factors like club characteristics or training volume (Guimarães et al., 2023). Interventions addressing gender differences in PA significantly improve participation for both boys and girls, with better gender-specific research leading to more consistent results (Schulze et al., 2021). Psychological factors, such as capacity and opinion comparisons, significantly affect junior athletes' motivation, self-efficacy, and performance in training, competition, and rehabilitation (Raievska et al., 2024). Gender differences in motivation impact PA levels, and males tend to exhibit higher intrinsic and extrinsic motivation than females (Sáez et al., 2021). In addition, mindfulness-based interventions combined with an SCT approach have been shown to significantly improve self-efficacy and dietary adherence among individuals with Type 2 Diabetes Mellitus (Harmiardillah et al., 2020). This suggests that similar strategies could enhance adolescents' self-efficacy and participation in basketball.

Interventions combining goal setting and physical training have proven effective. For example, a combination of SMART goal setting and core strength training was more effective than either approach alone in improving adolescents' fitness and exercise attitudes (Lu et al., 2022). Similarly, while enjoyment did not significantly change over a 12-week exergaming intervention, it was significantly higher during exergaming sessions compared to physical education classes, influenced by factors such as BMI and weekly PA levels (Röglin et al., 2023). Autonomous motivation during school recess and positive attitudes toward PA were key predictors of intentions toward physical activity, and they mediate the relationship between motivation and behavioral intentions (Pasi et al., 2021). Goal orientation and self-efficacy significantly influence adolescent athletes' performance and behavioral inten-

tions, particularly in managing competitive cognitive anxiety. Task orientation and low ego-orientation help buffer anxiety's impact on performance, while self-efficacy remains key to improving both performance and intentions (Peng & Zhang, 2023). Self-efficacy and goal changes significantly moderate the decline in physical activity during adolescence, particularly in students who maintain high self-efficacy beliefs, where changes in goals may have differing effects on physical activity (Dishman et al., 2019). Self-efficacy plays a mediating role between modeling after role models and achieving a flow state, demonstrating its importance in enhancing adolescent athletes' performance during sports activities (Lee, Kwon, & Ahn, 2021). Globally, 80% of adolescents are insufficiently active, with excessive screen time contributing to cardiovascular and mental health disorders (Van Sluijs et al., 2021). In order to improve PA, solutions should focus on supportive schools, social and digital environments, and multi-use urban spaces. Team sports like basketball are associated with fewer mental health issues, such as anxiety and depression, compared to individual sports (Hoffmann et al., 2022), and they predict reduced symptoms of depression and anxiety over time (Graupensperger et al., 2021). Additionally, positive attitudes toward physical education, parental support, and active transportation to school are strong predictors of PA participation (Rullestad et al., 2021). Adolescent athletes in contact sports show higher competitive aggression, while self-esteem predicts affiliation in non-contact sports athletes, suggesting that psychological constructs like emotional regulation and self-esteem play a key role in adolescent sports behavior and interventions (Huđin, Glavaš, & Pandžić, 2020).

The Theory of Planned Behavior (TPB) highlights that attitudes, subjective norms, and perceived behavioral control positively influence adolescents' participation in PA, which then leads to actual participation (Baek et al., 2020). Prior knowledge enhances attitudes and intentions, highlighting the importance of education and marketing in promoting sports. The Teaching Personal and Social Responsibility (TPSR) model significantly increases personal and social responsibility, prosocial behavior, and self-efficacy in youth soccer players compared to conventional methods (Carreres-Ponsoda et al., 2021). Reflective (e.g., intention stability and perceived control) and automatic motivation (e.g., identity) are key moderators of the intention-PA relationship, which explain the gap between intention and participation (Rhodes et al., 2022).

In conclusion, this 12-week SCT-based intervention aims to enhance self-efficacy, adjust outcome expectations, and strengthen social support and self-regulation among adolescent basketball players in Guangxi Province, China. By examining gender-specific responses, the study offers insights for developing gender-sensitive sports programs. Team sports, like basketball, are associated with fewer mental health issues and lower anxiety and depression over time. Addressing gender differences and leveraging SCT strategies can enrich the evidence for inclusive youth sports programs across diverse cultures.

Materials and Methods

Study Participants

The participants who met the inclusion criteria totaled 175 adolescents aged 12 to 14 years old and belonged to basketball clubs in Guangxi Province and were divided

into male ($n = 88$) and female ($n = 87$) groups. The study objectives and procedures were explained to the participants who subsequently provided written informed consent. This study was approved by the Mahasarakham University Ethics Committee (Approval number: 121-071/2024).

Inclusion Criteria

1. Male and female adolescents aged 12–14 years from clubs in Guangxi Province who are actively engaged in basketball training.
2. Participants have training experience in their basketball clubs for an average of approximately 2.4 years.

Exclusion Criteria

Players with physical injuries, chronic illnesses, or other medical conditions that may hinder their full participation in basketball training or intervention activities.

Players who had missed more than 30% of their training sessions in the past three months.

Study Design

This study was a quasi-experimental design with a single experimental group stratified by gender to analyze the effects of the intervention. The experimental group participated in a structured 12-week basketball intervention program, conducted twice a week for 90 minutes per session. The intervention activities included targeted training, team-based activities, and parental support components aimed at improving self-efficacy, strengthening peer and parental support, and aligning outcome expectations with the SCT principles (Table 1).

Research Instruments

The research instrument for this study consisted of a revised questionnaire based on the SCT, focusing on five key dimensions: self-efficacy, social support, situational factors, outcome expectations, and behavioral intentions. The questionnaire was validated through a pilot test conducted with 100 participants. The test demonstrated high reliability (Cronbach's α : 0.896–0.974) and validity (Kaiser–Meyer–Olkin test: 0.972, Bartlett's test of sphericity $\chi^2 = 18107.471$, $p < 0.001$). These adjustments ensured the instrument's appropriateness and accuracy for assessing adolescents' behavioral intentions in basketball training.

Statistical Analysis

General information is described using descriptive statistics (such as frequency, percentage, mean, and standard deviation). The Shapiro–Wilk test was conducted to examine the distribution of the data. Differences between results before and after the experiment were analyzed using paired sample t-tests and that between the results of the male and female groups were analyzed using independent sample t-tests. The level of statistical significance was set at 0.05.

Results

In this study, 175 adolescent basketball players participated in a 12-week intervention program aimed at enhancing behavioral intentions and key health-related constructs. The sample was nearly evenly divided by gender, comprising 50.29% males ($n=88$) and 49.71% females ($n=87$). The average age was similar across genders, with males averaging 13.21 years (standard deviation = 0.46) and

Table 1 Factor interventions for male and female adolescents

	Week	Intervention Item	Activity	Time	Content
Male	Weeks 1–4	Social Support (Q3)	Family day activities	3 rd week of the 1 st and 2 nd months, Wednesday evening, 6:00–9:00 PM	Parent-child basketball games, family interaction with the coach, and activities for parents to observe and interact.
	Weeks 1–4	Situation (Q16)	Coach Training	2 nd week of the 1 st and 2 nd months, Friday evening, 6:00–9:00 PM	Provide training and communication skills courses for coaches.
	Weeks 1–12	Self-Efficacy (Q25)	Psychological counseling	After training every Tuesday	Role model selection, positive feedback, and support methods.
	Weeks 1–12	Outcome Expectations (Q36)	Time management training	1 st week of each month, Thursday evening, 6:00–7:30 PM	Provide time management and study skills training.
Female	Weeks 1–4	Situation (Q16)	Coach training	2 nd week of the 1 st and 2 nd months, Friday evening, 6:00–9:00 PM	Provide training and communication skills courses for coaches.
	Weeks 1–12	Self-Efficacy (Q25)	Confidence-building courses	After training every Tuesday	Group discussions and counseling sessions.
	Weeks 5–8	Outcome Expectations (Q30)	Reward system	1 st week of each month, Thursday evening, 6:00–7:30 PM	Implement a reward program with parental involvement.

Table 2. Characteristics of study participants (n = 175)

Variables	Numbers (Percentage)	
Gender	Male (n = 88)	Female (n = 87)
	50.29%	49.71%
Age (years)	13.21 ± 0.46	13.01 ± 0.28
Experience in basketball training		
1 year and below	11	32
1–2 years	14	24
2–3 years	19	19
3–4 years	15	7
4–5 years	10	2
More than 5 years	19	2
Frequency of basketball training time		
4 hours and below	27	50
4–8 hours	13	23
8–12 hours	9	7
More than 12 hours	39	6

females 13.01 years (standard deviation = 0.28). Key findings revealed that male participants had a more diverse range of basketball training experiences, with a significant proportion (21.6%) having more than five years of training. In contrast,

a larger percentage of female participants (36.8%) had one year or less of training experience. Additionally, males were more likely to engage in extensive weekly training, with 44.3% training more than 12 hours per week compared to only 6.9% of females. Conversely, the majority of female participants (57.5%) trained four hours or less weekly.

Table 3 presents the pre- and post-intervention mean scores for the SCT constructs by gender. The intervention significantly improved all constructs ($p < 0.001$), with female adolescents showing particularly notable improvements in behavioral intentions and self-efficacy. For example, behavioral intention scores increased from 3.3 to 4.27 in female adolescents and from 3.19 to 3.77 in male adolescents.

Table 4 compares gender differences in social support, outcome expectations, and behavioral intentions. For pre-intervention, these constructs showed no statistically significant differences between genders (social support: $p = 0.2$; outcome expectations: $p = 0.099$; and behavioral intention: $p = 0.72$). For post-intervention, although scores for both genders increased, the differences remained statistically insignificant (social support: $p = 0.34$; outcome expectations: $p = 0.66$; and behavioral intention: $p = 0.86$).

Table 5 further compares the changes in situational factors and self-efficacy between genders. Prior to the intervention, the differences between male and female adolescents were not statistically significant (situational factors: $p = 0.14$; self-efficacy: $p = 0.18$). Post-intervention, both genders demonstrated significant improvements,

Table 3. Comparing pre-test and post-test scores for each gender after 12 weeks of intervention

Variables	Male			Female		
	Pre-test	Post-test	p-value	Pre-test	Post-test	p-value
Social Support	3.42	4.09	0.001	3.21	4.18	0.001
Situational factors	3.57	4.37	0.001	3.39	4.12	0.001
Self-efficacy	3.51	4.22	0.001	3.26	4.23	0.001
Outcome Expectations	3.59	4.24	0.001	3.36	4.05	0.001
Behavioral intention	3.19	3.77	0.001	3.3	4.27	0.001

$p < 0.05$, significant

Table 4. Comparison of social support, outcome expectations, and behavioral intention between genders after 12 weeks of intervention

Variable	Pre-test		p-value	Post-test		p-value
	Male	Female	Pre-test between genders	Male	Female	Post-test between Genders
Social Support	3.37	3.17	0.20	4.05	4.16	0.34
Outcome Expectations	3.59	3.35	0.09	4.24	4.29	0.66
Behavioral intention	3.19	3.24	0.72	3.77	3.79	0.86

Table 5. Comparison of situational factors and self-efficacy between genders after 12 weeks of intervention (cont.)

Variable	Pre-test		p-value	Post-test		p-value
	Male	Female	Pre-test between genders	Male	Female	Post-test between genders
Situational factors	3.57	3.35	0.144	4.34	4.36	0.80
Self-efficacy	3.52	3.32	0.185	4.24	4.28	0.69

but the differences between male and female adolescents remained insignificant (situational factors: $p = 0.80$; self-efficacy: $p = 0.69$).

Discussion

Post-intervention, behavioral intention scores increased from 3.19 to 3.77 for males and from 3.3 to 4.27 for females ($p < 0.001$). This improvement supports recent studies that behavioral intention is a key predictor of PA participation among adolescents (Liu et al., 2022). Our intervention, which included psychological counseling, family day activities, and a reward system, effectively boosted intentions, particularly among females. This finding is consistent with Schulze et al. (2021), who found that gender-sensitive interventions narrow the gender gap in PA participation. Additionally, Zhang et al. (2022) emphasized that social support and self-efficacy are critical predictors of behavioral intentions, which aligns closely with our intervention design.

Self-efficacy scores significantly improved post-intervention (from 3.51 to 4.22 for males and from 3.26 to 4.23 for females) ($p < 0.001$). This aligns with recent research emphasizing the importance of self-efficacy in PA participation among adolescents (Zhang et al., 2022). Our intervention enhanced self-efficacy through role models, positive feedback, and support methods. Notably, females showed greater improvement in self-efficacy, likely due to the confidence-building group discussions and psychological counseling tailored to them. This contrasts with Sáez et al. (2021), who found higher self-efficacy in males, suggesting that targeted interventions can help females achieve comparable improvements.

Social support scores significantly increased post-intervention (from 3.42 to 4.09 for males and from 3.21 to 4.18 for females) ($p < 0.001$). This aligns with Zhang et al. (2022), who highlighted the importance of family and peer support in sustaining adolescent PA participation. Our intervention strengthened support networks through family day activities and coach training. Additionally, situational factor scores improved significantly, increasing from 3.57 to 4.37 for males and from 3.39 to 4.12 for females ($p < 0.001$). This is consistent with Guimarães et al. (2023), who noted that training experience and environmental support influence performance. Our intervention addressed these factors through time management training and a reward system, helping adolescents balance academics and sports.

Outcome expectation scores significantly improved post-intervention (from 3.59 to 4.24 for males and from 3.36 to 4.05 for females) ($p < 0.001$). This aligns with Lu et al. (2022), who found that goal setting and reward mechanisms significantly enhance adolescents' motivation and outcome expectations. Our intervention, which included time management training and a reward system, helped adolescents clarify their goals and the significance of sports, thereby boosting their outcome expectations.

Although both male and female adolescents showed significant improvements across all constructs post-intervention, gender differences were not statistically significant ($p > 0.05$). This contrasts with Fredricks and Eccles (2006), who noted more barriers to PA participation for females. Our study, however, demonstrates that gender-sensitive interventions, such as confidence-building courses for females and family-oriented activities for males, can

effectively narrow the gender gap. This is consistent with Schulze et al. (2021), who highlighted the positive impact of such approaches on PA participation.

Conclusion

This 12-week intervention program significantly improved adolescents' social support, situational adaptability, self-efficacy, outcome expectations, and behavioral intentions in both genders. Although the gender differences in intervention effects were minimal, female adolescents demonstrated more substantial improvements in some dimensions, underscoring the importance of gender-sensitive intervention designs. The study findings further support the application of the SCT in understanding and enhancing behavioral intentions for sports participation. Future interventions should consider incorporating more tailored approaches to maximize adolescents' engagement and outcomes in sports training programs.

Recommendations

Recommendations for the study implication:

1. The findings suggest that schools in China, particularly in Guangxi Province, can adopt basketball intervention programs based on the SCT to promote adolescents' participation in physical activities.
2. A structured and targeted intervention program (e.g., enhancing social support, situational adaptability, and self-efficacy) can significantly improve adolescents' behavioral intentions and participation in basketball training.

Recommendations for further research:

1. Future studies should focus on the long-term effects of SCT-based intervention programs on adolescents' sports participation and overall health to assess the sustainability of behavioral changes.
2. Further research could explore the integration of technology (e.g., mobile apps or online platforms) into intervention programs to provide flexible and scalable delivery methods.
3. Expanding the study to include more diverse regions and age groups in China would provide a broader understanding of how SCT-based interventions influence adolescents' sports behavior and intentions across different cultural and demographic contexts.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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Розгляд впливу 12-тижневої інтервенційної програми на поведінкові наміри та пов'язані зі здоров'ям ключові конструкти у баскетболістів підліткового віку

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

Реферат. Стаття: 8 с., 5 табл., 32 джерела.

Мета дослідження. Метою цього дослідження було оцінити вплив 12-тижневої інтервенційної програми з баскетболу на поведінкові наміри підлітків та пов'язані зі здоров'ям ключові конструкти, включаючи самоефективність, соціальну підтримку, ситуативні фактори та очікувані результати, ґрунтуючись на соціально-когнітивній теорії (СКТ) та акцентуючи увагу на представниках кожної статі із проведенням порівняльного аналізу для обох статей.

Матеріали та методи. У дослідженні взяли участь 175 підлітків (вік: 12-14 років) з баскетбольних клубів провінції Гуансі, Китай. Учасників було розподілено за статевою приналежністю на дві групи (чоловіча [n = 88] та жіноча [n = 87] групи), які проходили інтервенційну програму впродовж 12 тижнів. Проведено перевірку валідності та надійності усіх вимірювань. З метою визначення предикторів поведінкових намірів, які використовувались для розроблення інтервенційної програми, було застосовано регресійний аналіз.

Результати. Інтервенція сприяла значному поліпшенню показників самоефективності, соціальної підтримки, ситуативних факторів, очікуваних результатів та поведінкових намірів як у підлітків чоловічої, так і жіночої статі. Показник поведінкових намірів у хлопців збільшився з 3,19 до 3,77 балів, а у дівчат — з 3,3 до 4,27 балів (p < 0,001). Крім того, відзначено зростання показників самоефективності з 3,51 до 4,22 у хлопців та з 3,26 до 4,23 у дівчат (p < 0,001). У представників обох статей також спостерігалось покращення інших конструкторів, причому значущих гендерних відмінностей у результатах після проведення інтервенції не встановлено (p > 0,05).

Висновки. Отримані дані вказують на ефективність впровадження 12-тижневої інтервенційної програми на основі СКТ, яка сприяла поліпшенню поведінкових намірів підлітків та пов'язаних з ними конструкторів. Розроблення гендерно-специфічних інтервенційних програм є важливою складовою для максимізації ефективності проведення інтервенції.

Ключові слова: поведінкові наміри, тренування з баскетболу, самоефективність, соціальна підтримка, ситуація, очікувані результати.

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Children's Fundamental Movement Skills, Social Emotional Development and Physical Activity Development Based on Kids' Athletics Intervention: SEM Modelling and Analysis

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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 developmental status of fundamental movement skills, social emotional development, and physical activity in Chinese children aged 7 to 10. Using the Kids' Athletics intervention, Structural Equation Modeling (SEM) was applied to analyze their developmental trajectories.

Materials and methods. The study was conducted between April and June 2024, and involved 305 primary school students. The Children's Fundamental Movement Skills Test, the Physical Activity Level Questionnaire for Children and Adolescents (ages 7-18), and the Student Social Emotional Competence Questionnaire were used to perform this study. SEM was applied to explore relationships among these developmental domains.

Results. In post-intervention period, significant improvements were noted in fundamental movement skills, social emotional competence, and physical activity levels (all $p < 0.05$). The experimental group outperformed the control group in most metrics, except balance beam walking and the others' perception dimension ($p < 0.05$). The structural model indicated an adequate fit, with path correlation analysis revealing a significant negative correlation between fundamental movement skills and social emotional development ($r = -0.33$, $p < 0.001$) and physical activity ($r = -0.24$, $p < 0.001$). Furthermore, social emotional development showed a positive correlation with physical activity ($r = 0.19$, $p = 0.001$) and a negative correlation with sedentary behavior ($r = -0.17$, $p = 0.005$). No significant correlations were observed between fundamental movement skills and sedentary behavior, or between different levels of physical activity.

Conclusions. The findings suggest that improved fundamental movement skills contribute to enhancing social emotional development and increasing physical activity while reducing sedentary behavior. This study provides a valuable framework for promoting physical literacy and optimizing physical education practices.

Keywords: fundamental movement skills, social emotional development, physical activity levels, kids' athletics in China.

Introduction

Despite research showing the benefits of physical activity (PA), fundamental movement skills (FMS), and social-emotional (SE) development in children, many, especially in China, do not meet PA recommendations (Yang et al., 2022; Liu et al., 2023; Peng et al., 2024). There is a lack of studies on holistic interventions for children aged 7 to 10 that integrate PA, FMS, and SE. Traditional physical education often fails to engage children, leading to poor FMS proficiency and health outcomes (Diao, 2018; Ulrich, 2019; Wang et al.,

2021). PA positively impacts children's overall health, yet FMS proficiency remains low due to barriers like academic pressure and lack of facilities (Barnett et al., 2016; Bolger et al., 2019; Meng et al., 2020; Xu et al., 2023). The Kids' Athletics program, developed by the IAAF, effectively promotes FMS and PA in an engaging, age-appropriate manner (Čillík et al., 2018; Katzenbogner et al., 2018).

The model integrates the ecological framework, health-related quality of life (HRQOL), social vulnerability index (SVI), and physical activity-related health competence model (PAHCO) (Sudeck & Pfeifer, 2016; Lemes et al., 2021; Amalia et al., 2021). Structural equation modeling (SEM) was used to analyze the relationships among FMS, SE, and PA. FMS enhancement was hypothesized to improve SE

development through increased motor competence and self-confidence. PA development, including increased moderate-to-high-intensity activity and reduced sedentary behavior, was expected to positively influence physical fitness and SE dimensions, such as self-management and social awareness. SEM systematically revealed these interactions.

This study evaluates the impact of the Kids' Athletics program on the development of fundamental movement skills (FMS), social-emotional (SE) development, and physical activity (PA) in Chinese children aged 7–10 years. A comprehensive model was constructed to provide an effective intervention approach, supporting children's physical, psychological, and social well-being during key developmental stages.

In this research model, the development of fundamental movement skills, social-emotional, and physical activity are the core dependent variables of the study and will be influenced by other potential variables of the model. Thus, the following hypotheses are proposed: Improving fundamental movement skills can promote the social-emotional development of children aged 7–10 years (H1); The improvement of fundamental movement skills plays a positive role in promoting medium to high intensity physical activities in children aged 7–10 years (H2); The development of fundamental movement skills can reduce sedentary behavior within a week in children aged 7–10 years (H3); The social-emotional development of children aged 7–10 years has a positive impact on their participation in moderate-to-high-intensity physical activities during the week (H4); The social-emotional development of children aged 7–10 years can reduce the time they spend in sedentary behaviors throughout the week (H5); Following the intervention, the relationship between weekly moderate to high intensity physical activity and sedentary behaviors was weakly correlated in children aged 7–10 years (H6).

Materials and Methods

Study Participants

The study included 305 children aged 7–10 years from Nanning, Guangxi, China, selected through cluster random sampling and divided into experimental ($n = 152$) and control ($n = 153$) groups. Participants included 50 boys and 54 girls aged 7–8, 47 boys and 50 girls aged 8–9, and 56 boys and 48 girls aged 9–10. Good health, the absence of moderate or severe cognitive impairment, and the signed informed consent of participants, parents/guardians, and school principals were requirements for inclusion. Cognitive disabilities, serious illnesses, or delays in motor development were among the exclusion criteria. There were 77 boys and 75 girls in the experimental group and 76 boys and 77 girls in the control group.

All protocols were approved by the Ethics Committee of Mahasarakham University, NO:184-038/2024.

Study Organization

From April to June 2024, 305 children aged 7–10 in Guangxi participated in a study using cluster random sampling. The quasi-experimental longitudinal design assessed the impact of the Kids' Athletics program on

fundamental movement skills (FMS), physical activity (PA), and social-emotional (SE) development across three phases:

1. Baseline Assessment: Assessed children's development of FMS, PA, and SE.

2. Intervention: Evaluated how well the Kids' Athletics program worked to enhance these areas.

3. Model Development: Constructed a successful intervention model and examined the correlations between variables.

The Chinese Fundamental Movement Skill Test (CFMST) was used to measure FMS. It assesses stability (reverse straight-line walking, balance beam walking), object control (kicking over obstacles, stationary ball shooting), and movement (sideways slide, single-leg hopping). CFMST has proven reliability and validity for Chinese children (Li & Liu, 2022).

Social-emotional development was measured using the Student Social-Emotional Competency Scale (Self-Assessment Version) by Mao Yaqing's team (validated by Yang et al., 2020; Yang et al., 2023). It includes 30 items across six dimensions (e.g., self-awareness, collective management) scored on a 5-point Likert scale. Reliability coefficients ranged from 0.786 to 0.872, with an overall Cronbach's alpha of 0.943. Fit indices (CFI=0.989, TLI=0.981, SRMR=0.017) confirmed the scale's strong reliability and validity.

Physical activity levels were assessed using the Physical Activity Level Evaluation for Children and Adolescents Aged 7–18 Years, a reliable and widely used standard in China's health industry.

The Kids' Athletics program comprised 8 weeks of game-based interventions, focusing on mobility, stability, object manipulation, and teamwork. Activities lasted 45 minutes each, four times a week, and had catchy game names that promoted involvement outside of the classroom.

Statistical Analysis

All outcome and demographic variables were subjected to standard descriptive statistics. SPSS 26.0 was used for statistical analysis, and AMOS 24.0 was used for structural equation modeling to investigate the connections between FMS, SE, and PA results.

Results

Overall Results after Intervention

With the exception of the walking-on-the-balance-beam test, the intervention markedly enhanced students' mobility abilities on the majority of assessments. The experimental group's mean time in this test was 3.58 seconds, whereas the control group's was 3.93 seconds. The t -value was 1.78 and the p -value was 0.076 ($p > 0.05$), which showed that there was no significant difference even though the experimental group's time was somewhat faster.

The experimental group's social-emotional competency ratings were noticeably higher, with the biggest gains being in self-awareness and group management. The experimental group's mean score was somewhat higher than the control group's for the «others' perception» dimension, but the difference was not statistically significant ($p > 0.05$), indicating that the intervention had little impact on this

Table 1. Overall of FMS, SE, PA in post-test (N=305)

Content	Control group (n = 153) M ± SD	Experimental group (n = 152) M ± SD	t-test	p-value
Sideways slide running	7.59 ± 1.58	7.20 ± 1.57	2.13	0.034*
Jumping continuously on one foot	4.23 ± 0.89	3.93 ± 0.82	3.03	0.003*
Changing hands and shooting the ball on the spot	4.05 ± 0.86	3.81 ± 0.83	2.50	0.013*
Kicking the ball over the obstacle	7.60 ± 2.72	6.92 ± 2.16	2.45	0.015*
Walking on the balance beam	3.93 ± 2.02	3.58 ± 1.29	1.78	0.076
Walking backward in a straight-line	13.34 ± 5.80	11.63 ± 4.00	3.00	0.003**
Self-awareness dimension total score	19.10 ± 4.22	21.38 ± 3.70	5.03	0.000***
Total score of self-management dimension	19.46 ± 4.63	20.87 ± 3.81	2.91	0.004**
Total score of others' perception dimension	18.41 ± 4.07	18.82 ± 4.11	0.88	0.381
Total score of others' management dimension	18.73 ± 4.23	20.24 ± 3.83	3.25	0.001***
The total score of collective cognition dimension	19.31 ± 4.79	21.31 ± 3.68	4.10	0.000***
The total score of collective management dimension	18.90 ± 4.36	20.31 ± 3.68	3.05	0.003**
Total score of social-emotional competencies	113.91 ± 23.68	122.93 ± 19.55	3.63	0.000***
Total weekly physical activity time	696.10 ± 449.22	811.19 ± 459.12	-2.21	0.028*
Total weekly sedentary behavior	946.14 ± 817.07	797.07 ± 449.23	1.98	0.049*

Note: *p < 0.05, **p < 0.01, ***p < 0.001

dimension. A longer intervention period or alternative methods may be needed.

Both total weekly and average daily physical activity times were significantly higher in the experimental group ($p < 0.05$), demonstrating the intervention's effectiveness in increasing activity levels. Sedentary behavior also decreased significantly in the experimental group ($p = 0.049$), nearing the significance threshold but still indicating a notable reduction in static behaviors.

Overall Results after Intervention Promotion

Significant enhancements were noted across all fundamental movement skill (FMS) metrics, characterized by reduced completion times in activities such as sideways slide running (decreasing from 8.15 to 7.39 seconds), single-leg hopping (from 4.48 to 4.08 seconds), and kicking a ball over obstacles (from 8.20 to 7.26 seconds), all yielding highly significant t-test outcomes ($p < 0.01$). Lower standard

Table 2. Pre-test and post-test difference statistics of FMS, SE, PA

Test content	Pre-test (n = 305) M ± SD	Post-test (N = 305) M ± SD	t-test	p
Sideways slide running	8.15 ± 1.22	7.39 ± 1.58	6.72	0.000***
Jumping continuously on one foot	4.48 ± 0.79	4.08 ± 0.87	6.02	0.000***
Changing hands and shooting the ball on the spot	4.10 ± 0.97	3.93 ± 0.85	2.37	0.018*
Kicking the ball over the obstacle	8.20 ± 2.65	7.26 ± 2.48	4.53	0.000***
Walking on the balance beam	4.11 ± 2.26	3.76 ± 1.70	2.18	0.030*
walking backward in a straight-line	14.29 ± 5.47	12.49 ± 5.05	4.29	0.000***
Self-awareness dimension total score	17.13 ± 2.19	20.24 ± 4.12	-11.63	0.000***
Total score of self-management dimension	16.76 ± 2.50	20.16 ± 4.29	-11.95	0.000***
Total score of others' perception dimension	17.2 ± 2.36	20.30 ± 4.38	-10.90	0.000***
Total score of others' management dimension	17.16 ± 2.47	19.60 ± 4.09	-8.94	0.000***
The total score of the collective cognition dimension	15.55 ± 2.63	18.62 ± 4.09	-11.00	0.000***
The total score of the collective management dimension	16.92 ± 2.95	19.48 ± 4.10	-8.87	0.000***
Total score of social-emotional competencies	100.72 ± 6.93	118.4 ± 22.15	-13.30	0.000***
Total weekly physical activity time	571.52 ± 587.32	753.46 ± 457.08	-4.26	0.000***
Total weekly sedentary behavior time	1103.85 ± 615.73	871.85 ± 663.04	20.96	0.000***

Note: *p < 0.05, **p < 0.01, ***p < 0.001

deviations in the post-test analysis showed an improvement in performance consistency. These outcomes confirm the efficacy of the intervention by highlighting gains in speed, coordination, balance, flexibility, and stability.

Significant improvements in self-awareness, self-management, social awareness, relationship management, collective awareness, and collective management were noted in the area of social-emotional (SE) development; post-test evaluations revealed significant increases in comparison to pre-test scores (t-values ranging from -8.87 to -13.30, $p < 0.001$). For instance, self-management scores increased from 16.76 to 20.16, and self-awareness ratings increased from 17.13 to 20.24. These results imply that the intervention greatly improved social engagement, emotional control, and teamwork.

Levels of physical exercise also showed significant improvement. Weekly moderate-to-vigorous physical activity duration increased from 571.52 to 753.46 minutes ($t = -4.26$, $p < 0.001$), an increase of 181.94 minutes (nearly 3 hours). A tendency toward more consistent engagement is indicated by the decline in standard deviations. Monthly sedentary behavior, on the other hand, decreased by 232 minutes (about 4 hours), from 1103.85 to 871.85 minutes, with a highly significant t-test result ($t = 20.96$, $p < 0.001$). These changes are a reflection of overall lifestyle improvements, including better social connections, mental wellness, academic performance, and physical health.

Intervention Model Construction and Result

For an SEM model to function effectively, it must be statistically and methodologically identifiable. A properly specified model meets key requirements, including standardized variance for latent variables and assigning a factor loading of 1 to one measured variable influenced by the latent variable, enabling free estimation of variance (Qiu & Lin, 2019).

FMS Observables: FMS was measured via six observable variables: sideways slide running (FMS1), continuous single-leg hopping (FMS2), stationary ball shooting (FMS3), kicking a ball over obstacles (FMS4), balance beam walking (FMS5), and backward straight-line walking (FMS6).

SE Observables: Social-emotional (SE) dimensions were measured using six variables: self-perception (SE1), self-management (SE2), others' perception (SE3), others' management (SE4), collective perception (SE5), and collective management (SE6).

PA Observables: Physical activity (PA) was evaluated with two variables: moderate-to-vigorous physical activity (PA1) and sedentary behavior (PA2).

Model Validation: The CFA model demonstrated good fit indices ($\chi^2/df = 2.435$, NFI = 0.921, CFI = 0.952, TLI = 0.942, RMSEA = 0.069), confirming the model's robustness in explaining relationships between motor skills, socio-emotional development, and activity levels.

Common Method Bias (CMB): The Harman one-factor test was used to evaluate CMB. The one-factor CFA model showed poor fit ($\chi^2/df = 6.731$, NFI = 0.779, CFI = 0.804, TLI = 0.786, RMSEA = 0.137, SRMR = 0.127), indicating minimal CMB in the model.

Reliability and Validity Metrics: FMS (CFMST Test): Cronbach's $\alpha = 0.618$, $\chi^2/df = 3.394$, NFI = 0.934, TLI = 0.920, CFI = 0.952, RMSEA = 0.089, SRMR = 0.048, indicating good construct validity.

SE Outcomes: Overall Cronbach's $\alpha = 0.943$, CFI = 0.989, TLI = 0.981, SRMR = 0.017, confirming strong reliability and validity.

PA Questionnaire: Cronbach's $\alpha = 0.85$ for moderate-to-vigorous activity and 0.72 for sedentary behavior, with structural validity verified through principal component analysis. Three key factors explained 63.7% of the total variance, and variables showed high loadings on expected factors, supporting validity.

These findings confirm the SEM model's methodological rigor, construct validity, and ability to assess relationships among FMS, SE, and PA effectively.

The results of the structural model fitness index analysis showed the following: $\chi^2/df=2.388$; RMSEA=0.068; GFI=0.927; NFI=0.926; IFI=0.955; CFI=0.955; PNFI (0.742), PCFI (0.766), PGFI (0.644) are all greater than 0.5. The results of the analyses show that the structural model of intervention effect has a good fit, that is, the theoretically hypothesized path relationship is more in line with the actual measured data, and the structural model construction and assumptions are more satisfactory (shown in Table 4).

Correlation Coefficients analysis

In the path correlation analysis, FMS was significantly negatively correlated with SE ($r = -0.33$, $p < 0.001$) and PA1 ($r = -0.24$, $p < 0.001$). SE showed a significant positive correlation with PA1 ($r = 0.19$, $p = 0.001$) but a significant negative correlation with PA2 ($r = -0.17$, $p = 0.005$). FMS and PA2 were not significantly correlated ($r = 0.12$, $p = 0.066$), nor were PA1 and PA2 ($r = 0.02$, $p = 0.756$).

Combining the model hypotheses and the results of the structural model analysis, the relationships between model variables were further tested, as summarized in Table 5. The results showed significant differences for all hypotheses except H3 and H6, which were not significant. The improvement in fundamental movement skills among 7–10-year-old children after the intervention significantly promoted social-emotional development and increased time spent in moderate- to high-intensity physical activities. Positive social-emotional growth also decreased sedentary behavior and increased engagement in moderate-to-high-intensity activities. However, neither the increase in moderate-to-high-intensity activity participation nor

Table 3. Structural model fit parameter results

Statistical	Absolute Fitness Index			Value Added Fitness Index			Simplicity Fitness Index		
	χ^2/df	RMSEA	GFI	NFI	IFI	CFI	NFI	CFI	GFI
Adaptation Standards	3	<0.08	>0.9	>0.9	>0.9	>0.9	>0.5	>0.5	>0.5
Parameters of the model	2.388	0.068	0.927	0.926	0.955	0.955	0.742	0.766	0.644

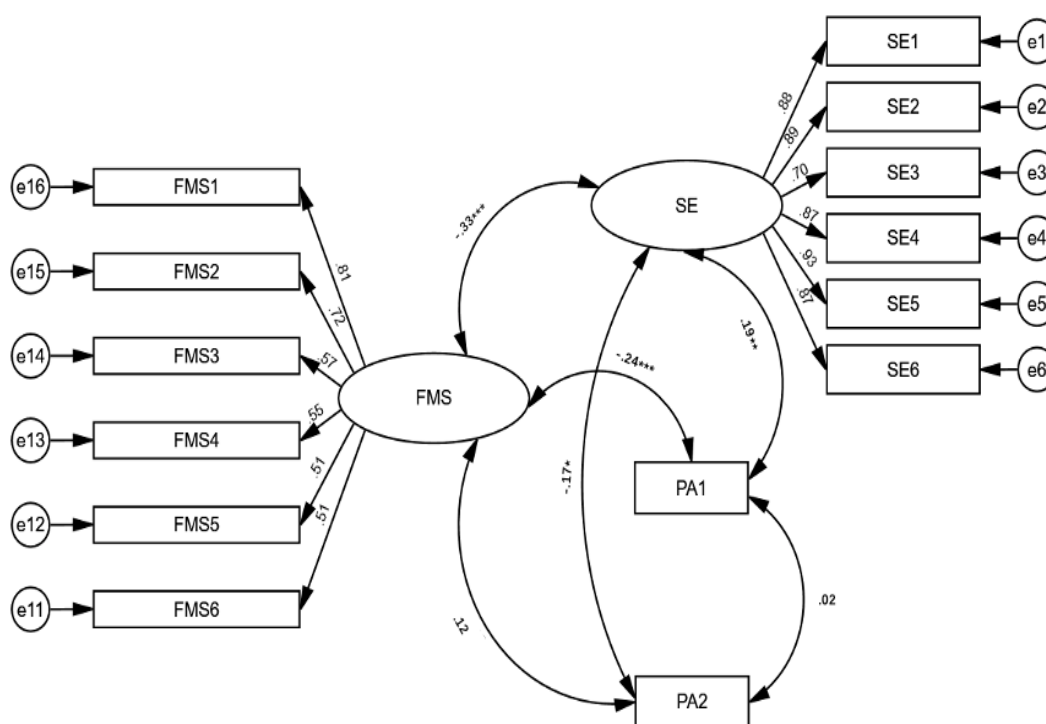


Fig. 1. Result of intervention structural equation modeling

the decrease in inactive time throughout physical activity development in this age group were significantly impacted by the improvement in fundamental movement abilities.

The results have shown that the most indices of model fit were at a good level. These findings underscore the need to disentangle types of activity participation and consider their unique relations with motor skill development. FMS impacted between activity levels PA1 and PA2, indicating children's activity participation is limited by their motor abilities and the way in which the activities are provided. This highlights the importance of interventions not just to support physical activity but also to encourage social-emotional development.

Discussion

Overview of the Main Hypothesis

This study formulated six hypotheses to examine the relationships between fundamental movement skills (FMS), social-emotional development (SE), and physical activity (PA):

H1: It was hypothesized that improvements in movement skills would enhance socio-emotional development. The findings supported this with a significant correlation ($r = -0.33$, $p < 0.001$).

H2 & H3: These hypotheses proposed that better FMS would lead to increased moderate-to-vigorous physical activity (PA1) and reduced sedentary behavior (PA2). The results supported both hypotheses, although the difference in H3 was not statistically significant ($r = 0.12$, $p = 0.066$). However, it still suggested that improved FMS could help reduce sedentary time to some extent.

H4 & H5: These hypotheses suggested that social-emotional development would increase PA1 and decrease PA2. The results confirmed these assumptions ($r = 0.19$ and $r = -0.17$, respectively), aligning with the theory that emotional regulation and social confidence encourage active participation.

H6: This hypothesis examined the relationship between PA1 and PA2 but found no significant correlation ($r = 0.02$), indicating that reducing sedentary behavior requires interventions beyond simply increasing PA.

Table 4. Hypothesis testing for each structural path

Hypothesis	Path	Standardized Estimate	Estimate	S.E.	C.R.	P
H1	FMS $\leftrightarrow$ SE	-0.33	-3.104	0.713	-4.315	***
H2	FMS $\leftrightarrow$ PA1	-0.24	-287.627	81.864	-3.513	***
H3	FMS $\leftrightarrow$ PA2	0.12	203.574	110.554	1.841	0.066
H4	SE $\leftrightarrow$ PA1	0.19	321.168	99.089	3.241	**
H5	SE $\leftrightarrow$ PA2	-0.17	-397.684	142.882	-2.783	*
H6	PA1 $\leftrightarrow$ PA2	0.02	5376.426	17327.635	0.310	0.756

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Discussion of Conclusions

In general, our primary hypothesis is substantiated in this research. The experiment and control groups had no difference in FMS or social-emotional competency prior to the intervention (all $p > 0.05$), indicating that both groups started at comparable baseline levels. This provided a solid foundation for assessing the actual impact of the Kids' Athletics program.

Following the Kids' Athletics program, the experimental group showed notable improvements in nearly all FMS measures compared to the control group. Skills such as sideways sliding ($p = 0.034$), one-foot continuous jumping ($p = 0.003$), changing hands to shoot ($p = 0.013$), kicking over obstacles ($p = 0.015$), and walking backward on a line ($p = 0.003$) all improved significantly. These enhancements reflect gains in children's speed, agility, balance, hand-eye coordination, reaction time, and spatial awareness. However, one skill—walking on a balance beam ($p = 0.076$)—did not show significant improvement, suggesting that this skill may require a longer intervention or more targeted training to yield noticeable progress.

Regarding social-emotional outcomes, the intervention group scored significantly higher than the control group in several SE dimensions after the program. Improvements were especially pronounced in self-awareness, self-management, management of others, collective awareness, and collective management skills. The most significant gains were observed in self-perception and collective management, highlighting the program's effectiveness in fostering children's self-awareness and teamwork abilities. However, the "Others' Perception" dimension did not show a significant improvement, possibly due to the short intervention duration or because the activities were not directly focused on this skill. This suggests that future implementations may require additional or adapted strategies to better cultivate children's awareness of others.

The Kids' Athletics program also had a positive impact on children's activity behaviors. The experimental group increased their moderate-to-vigorous physical activity by an average of about 115 minutes per week ($t = -2.21$, $p = 0.028$) more than the control group and reduced their sedentary time by approximately 149 minutes per week ($t = 1.98$, $p = 0.049$) compared to controls. These findings suggest that students not only enjoyed the activities but also began adopting more active lifestyles, spending less time on sedentary pursuits. While the reduction in sedentary behavior was statistically significant, the magnitude of change was modest, indicating room for further improvement in decreasing inactive time.

Most importantly, SEM analysis confirms the interconnected nature of these outcomes. The structural model demonstrated a good fit ($\chi^2/df = 2.388$; NFI = 0.926; CFI = 0.955; IFI = 0.955; RMSEA = 0.068; SRMR = 0.066), validating the proposed relationships among FMS, SE, and PA. According to the model's path coefficients, the development of FMS had a significant positive effect on children's SE development (path coefficient = 0.33). In other words, as children's fundamental movement skills improved, their social-emotional competence also increased. This makes intuitive sense: better motor skills likely enhanced children's confidence, self-control, and opportunities for positive social interaction, thereby improving various aspects of their social-emotional skills.

Our results align with and extend previous research findings in this field. Consistent with national trends noted by Yang et al. (2022) and colleagues, children in

our sample initially exhibited suboptimal physical activity levels and similar fundamental movement skill proficiency, highlighting the need for interventions. Past studies have indicated that traditional physical education programs often fail to sufficiently engage children or improve FMS (Diao, 2018; Ulrich, 2019; Wang et al., 2021). Our baseline assessment corroborates these findings, showing no notable differences between groups, suggesting that without a specialized program, regular school activities may not be enough to enhance these skills or behaviors.

The significant motor skill improvements observed with the Kids' Athletics intervention align with the findings of Çillik et al. (2018) and Katzenbognner et al. (2018), who demonstrated that the IAAF Kids' Athletics program effectively promotes FMS and physical activity in children. Our study reinforces these results in a Chinese context while also emphasizing gains in agility, coordination, and balance through specific skill assessments. Additionally, previous studies have well established that increased physical activity yields health benefits for children (Barnett et al., 2016; Bolger et al., 2019; Meng et al., 2020; Xu et al., 2023). Our findings build on this body of evidence by showing that a targeted program can significantly increase weekly PA levels and reduce sedentary time, directly addressing the concern that many children do not meet recommended PA guidelines (Yang et al., 2022; Liu et al., 2023; Peng et al., 2024).

Practical Applications of the Results

Since FMS is inextricably linked to social-emotional learning, schools and youth sports programs must accord FMS training top priority. The inclusion of exercises for enhancing performance in basic motor skill functions such as jumping, balancing, and throwing in curricula can allow youths to develop motor competency, confidence, and social skills, thereby contributing to their overall development. The benefits of physical activity for children vary based on their FMS skill level. It is thus highly important to consider their current abilities when designing activity programs. By structuring programs to accommodate all skill levels, educators can ensure that each child is appropriately challenged and experiences success. On a policy and curriculum level, a balanced program incorporating moderate and vigorous activities, cooperative games, and skill drills can maximize developmental outcomes.

With these findings in mind, schools and trainers can develop interventions and programs that seamlessly integrate active lifestyles with social-emotional learning. For instance, physical education classes can incorporate teamwork-based games and challenges that emphasize communication and collaboration alongside fitness. Similarly, youth sports coaches can include reflective discussions on teamwork and self-discipline in training sessions, reinforcing the link between physical skill development and emotional growth.

Importance of the Study Findings

This research supports a whole-child conceptualization for child development in the context of physical education. Our findings affirm improvement in bodily capacities is highly connected to improvement in social-emotional domains—a connection supporting integrated interventions

as being highly effective. The evidence supporting a sports-based program in improving self-perception, self-regulation, and inter-person capacities contributes usefully to closing research gaps in integrated physical activity and social-emotional interventions in early childhood (Yang et al., 2022). Moreover, close correspondence between our SEM model and seeming inter-relationship between domains (FMS $\leftrightarrow$ SE $\leftrightarrow$ PA) provide empirical substantiation for theoretical frameworks proposing inter-connected child development. Practically, this advises interventions for child motor skill improvement should not be thought of as a method for improving bodily health but as a method for improving affect and relationships as much as possible. The significance in our findings is in demonstrating a structured program in physical activity can be a basis for generalizable learning outcomes. That justifies widening the mission for physical education beyond health-fitness to include key personal development domains like confidence, teamwork, and self-regulation. By shedding lights on inter-relationship between them, our research compels decision-makers and educators to invest in integrated programs (like Kids' Athletics or programs like it) addressing multiple dimensions in child development at once.

Future Research Directions

Some skills, such as balance-related abilities and social-emotional learning aspects like «Others' perception,» showed limited improvement. Future interventions should extend program duration or adjust content to address these areas more effectively. Long-term studies are needed to determine whether improvements in fundamental movement skills, social-emotional learning, and physical activity persist over time and whether they translate into other benefits like academic performance or long-term health. Additionally, self-reported physical activity data revealed inconsistencies, emphasizing the need for objective measurement methods. Further research should explore the link between increased physical activity and reduced sedentary time to improve future intervention strategies.

Conclusions

These findings lend strong support for the capability of well-structured playful interventions like the Kids' Athletics program for enhancing children's fundamental movement skills, social-emotional development, and rates of physical activity. The findings underscore the integrated nature of these aspects of development and the necessity of the integrated delivery of youth education and the promotion of physical activity.

These results reinforce that the improvement of fundamental movement skills improves more than mere motor ability but also affects positive social-emotional development and provokes enhanced levels of physical activity with diminished sedentary behavior. These conclusions underscore the need for the development and implementation of physical activity interventions that simultaneously affect multiple aspects of children's development. And the significant relationship between increased physical activity behaviors and reduced sedentary behaviors needs to be supported by additional research findings.

Interventions of the future must consider the extension and enhancement of the approaches of training toward more effectively providing areas of improvement that were weaker, such as balance-related ability and the development of social awareness. Durability of these improvements over the years and the more widespread effect upon education and health must be determined by longitudinal study. Policymakers and teachers are more effectively enabled by the implementation of such knowledge to build more successful interventions that benefit children's health and well-being, leading toward the enhancement of long-term development.

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Conflict of Interest

The authors have no conflicts of interest.

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Фундаментальні рухові навички дітей, соціально-емоційний розвиток та розвиток фізичної активності на основі інтервенції з дитячої легкої атлетики: Метод моделювання структурними рівняннями (SEM) та аналіз

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

Реферат. Стаття: 6 с., 4 табл., 1 рис., 19 джерел.

Мета дослідження. Мета цього дослідження полягала у вивченні стану розвитку основних рухових навичок, соціально-емоційного розвитку та фізичної активності у китайських дітей віком від 7 до 10 років. Використовуючи інтервенцію з дитячої легкої атлетики, для аналізу траєкторій їхнього розвитку було застосовано метод моделювання структурними рівняннями (SEM).

Матеріали та методи. Дослідження проводилось у період з квітня по червень 2024 року за участю 305 учнів початкової школи. Задля проведення дослідження використовували тест на визначення рівня фундаментальних рухових навичок у дітей, опитувальник для оцінки рівня фізичної активності дітей та підлітків (7-18 років) та опитувальник соціально-емоційної компетентності учнів. З метою вивчення взаємозв'язків між зазначеними сферами розвитку було застосовано метод моделювання структурними рівняннями.

Результати. Після завершення інтервенційного періоду спостерігалось значне покращення показників основних рухових навичок, соціально-емоційної компетентності та рівнів фізичної активності (усі показники $p < 0,05$). Експериментальна група перевершила контрольну групу за більшістю показників, окрім виконання ходьби на гімнастичній колоді з метою визначення рівноваги тіла та оцінки сприйняття оточуючих ($p < 0,05$). Структурна модель показала адекватну відповідність, а кореляційний аналіз шляхів виявив значну негативну кореляцію між основними руховими навичками та соціально-емоційним розвитком ($r = -0,33$, $p < 0,001$) і фізичною активністю ($r = -0,24$, $p < 0,001$). Крім того, соціально-емоційний розвиток продемонстрував позитивну кореляцію з фізичною активністю ($r = 0,19$, $p = 0,001$) і негативну кореляцію з малорухливою поведінкою ($r = -0,17$, $p = 0,005$). Значущих кореляцій між основними руховими навичками та малорухливою поведінкою, а також між різними рівнями фізичної активності не спостерігалось.

Висновки. Отримані дані дозволяють зробити висновок, що покращення фундаментальних рухових навичок сприяє поліпшенню соціально-емоційного розвитку та підвищенню рівня фізичної активності, а також зниженню малорухливої поведінки. Це дослідження забезпечує цінну основу для популяризації фізичної грамотності та оптимізації практик фізичного виховання.

Ключові слова: фундаментальні рухові навички, соціально-емоційний розвиток, рівні фізичної активності, дитяча легка атлетика в Китаї.

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Measuring the Parameters of Maximum Muscle Strength, Muscle Mass, Muscle Damage in Active Adult Males after Low-Load High-Repetition with High-Load Low-Repetition Resistance Training

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Abstract

Objectives. This study aimed to evaluate the effects of high-load, low-repetition (HLLR) and low-load, high-repetition (LLHR) resistance training protocols on muscle strength, muscle mass, and muscle damage in active adult males.

Materials and methods. This quasi-experimental study involved 28 active adult males aged 18-22 years with a body mass index of 19-23 kg/m² selected to actively participate in the study and given HLLR and LLHR interventions with a frequency of 3x/week for 4 weeks. Data collection was carried out by assessing maximum muscle strength, muscle mass, and muscle damage between baseline (pre) and week 4 (post). Statistical analysis used an independent sample t-test, with a significance level of 95%.

Results. There were significant differences between HLLR and LLHR interventions in max strength lower body (effect size (ES): 1.024), max strength upper body (ES: 1.241), and muscle mass (ES: 1.184) ($p < 0.05$). Meanwhile, CK activity was found to be significantly reduced in LLHR compared to HLLR (ES: 0.828) ($p < 0.05$).

Conclusions. This study demonstrated that high-load, low-repetition (HLLR) training was more effective for increasing muscle strength and muscle mass, while low-load, high-repetition (LLHR) training reduced muscle damage, as indicated by lower creatine kinase levels.

Keywords: maximum muscle strength, muscle damage, muscle mass, resistance training.

Introduction

Resistance training is integral to physical fitness, rehabilitation, and athletic performance, being widely recognized as a foundational element for enhancing muscle strength, promoting hypertrophy, minimizing muscle damage, and sustaining functional capacity across diverse populations (Lopez et al., 2020). As an exceptionally adaptable form of exercise, resistance training can be customized to address the specific requirements of athletes, older adults, and individuals undergoing rehabilitation (Fragala et al, 2019; Bjarnason-Wehrens et al., 2022;

Papa et al., 2017). Among the most commonly utilized resistance training modalities are high-load, low-repetition (HLLR) and low-load, high-repetition (LLHR) approaches (Liu et al., 2024). HLLR, characterized by heavier loads (exceeding 70 % of one-repetition maximum, 1RM) and fewer repetitions, is traditionally preferred for maximizing strength via the recruitment of high-threshold motor units and generating greater mechanical tension on type II muscle fibers (Schoenfeld et al., 2015; Nóbrega & Libardi, 2016). In contrast, the LLHR protocol, which employs lighter loads (at or below 50% of 1RM) with higher repetitions, is frequently associated with hypertrophy through mechanisms involving metabolic stress and sustained motor unit activation, offering an alternative for populations emphasizing reduced muscle damage and expedited recovery (Dobson, 2021). Despite the widespread application of these protocols, ongoing investigations focus on their relative efficacy and associated trade-offs concerning key muscular adaptations.

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Prior studies have compared LLHR and HLLR in various contexts. For instance, Ikezoe et al. (2017) reported no significant differences in muscle strength or hypertrophy between the two protocols when repetitions in LLHR were sufficiently increased, suggesting that LLHR could serve as a viable alternative to HLLR. Likewise, Schoenfeld et al. (2017) concluded in their meta-analysis that while hypertrophy can be attained across a spectrum of loads, maximal strength gains are most effectively achieved through higher loading protocols. However, critical distinctions emerge regarding muscle damage and recovery requirements. Yeom et al. (2023) demonstrated that LLHR is associated with lower levels of muscle damage markers, such as creatine kinase (CK) and lactate dehydrogenase (LDH), compared to HLLR, positioning LLHR as advantageous for populations necessitating faster recovery. Additionally, studies by Schoenfeld et al. (2015) and Bello et al. (2024) revealed that while HLLR yields superior strength adaptations, LLHR excels in improving muscular endurance. These findings underscore the necessity of discerning the physiological trade-offs inherent to these resistance training methods.

Nonetheless, several critical gaps persist in the literature. Firstly, existing studies have predominantly concentrated on narrow populations, such as untrained or well-trained young males, limiting the generalizability of results to broader demographics, including older adults or individuals engaged in rehabilitation (Schoenfeld et al., 2015; Fragala et al., 2019). Secondly, while the improvements in hypertrophy and strength resulting from these protocols have been extensively elucidated, the implications for muscle damage and recovery duration remain inadequately explored, particularly in active adult males representing a wider spectrum of fitness levels (Yeom et al., 2023; Dobson, 2021). Thirdly, the long-term consequences of integrating LLHR and HLLR for optimizing both hypertrophy and recovery have yet to be systematically investigated. Lastly, while studies by Ikezoe et al. (2017) and Yeom et al. (2023) infer that LLHR can achieve outcomes comparable to HLLR, evidence remains scarce regarding the applicability of these benefits in populations prioritizing reduced recovery demands or minimized joint stress.

To address these gaps, this study endeavors to directly compare the effects of LLHR and HLLR on muscle strength, muscle mass, and muscle damage within active adult males. Specifically, the research aims to ascertain whether LLHR can achieve comparable hypertrophic and strength adaptations while simultaneously reducing muscle damage relative to HLLR. By examining these variables in conjunction, this investigation aspires to deliver significant insights into the relative advantages and limitations of each training protocol, thus providing practical guidance for the customization of resistance training to align with individual objectives and capacities.

This research enriches the expanding corpus of literature on resistance training by clarifying the trade-offs between load and repetition schemes, emphasizing their integration to achieve balanced training outcomes while considering recovery demands. Ultimately, the findings aim to inform evidence-based practices for athletes, fitness enthusiasts, and clinical populations, addressing both performance enhancement and recovery management.

Materials and Methods

Study Design

This study was a two-group pretest-posttest quasi-experimental design. A total of 28 active adult males aged 18-22 years, body mass index 19-23 kg/m², had normal blood pressure, normal resting heart rate, normal oxygen saturation, and no history of chronic diseases, including heart failure, coronary heart, diabetes mellitus, hypertension, and chronic lung disease and no history of alcohol consumption and no smoking in 5 years were selected to be actively involved in the study. The participant recruitment technique used consecutive sampling and was divided into two intervention groups, namely high-load, low-repetition (HLLR; $n = 14$) and low-load, high-repetition (LLHR; $n = 14$). All participants involved in the study had received information about the purpose, benefits, and risks of participation and they had given informed consent. Following informed consent, all subjects underwent health screenings and pretests for maximum muscle strength, muscle mass, muscle damage.

Protocol of high-load, low-repetition (HLLR) and low-load, high-repetition (LLHR)

The HLLR and LLHR training programs were implemented and supervised by professional coaches from the Department of Sports Coaching Education, Faculty of Sports and Health Sciences, Universitas Negeri Surabaya to ensure that the movements performed were correct. HLLR was implemented with bench press and leg extension exercises performed 3-5 sets, 8-12 repetitions, with an intensity of 80-90 % 1RM. LLHR was implemented with bench press and leg extension exercises performed 3-5 sets, 25-35 repetitions, with an intensity of 40-50 % 1RM. The repetition rhythm was performed in a controlled manner with concentric contractions of about 1 second and eccentric actions of about 2 seconds. Rest between sets was done for 90 seconds. The HLLR and LLHR training programs were implemented with a frequency of 3x/week for 4 weeks.

Data Collection Technique

Assessment of maximum muscle strength, muscle mass, muscle damage was carried out at the baseline (pre) and week 4 (post) in each group. Maximal muscle strength, namely maximum strength lower body and maximum strength upper body was assessed using the 1RM test, namely with leg extension (lower body) and bench press (upper body). Muscle mass was assessed using the TANITA BC-545N. Muscle damage was assessed by measuring Creatine kinase (CK) Activity in serum using an Assay Kit (Cat.No.: E-BC-K558-S; CK Activity; Elabscience Biotechnology Inc., Houston, TX 77079, USA).

Statistical Analysis

Normality was applied using the Shapiro-Wilk Test, then the normally distributed data were tested for differences using the paired sample t-test to observe changes between baseline (pre) and week 4 (post) in each group in all variables. Meanwhile, to observe differences between

groups, the independent sample t-test was applied. Effect size analysis using Cohen's D. All statistical analyses used a 95% significance level. Statistical analyses were performed using SPSS 21.0 for Windows 10.

Results

Details of the baseline characteristics of the study participants are presented in Table 1. No significant differences were found in baseline characteristics of study participants between groups (all $p > 0.05$). Assessment of maximum muscle strength, muscle mass, muscle damage at baseline (pre) and week 4 (post) on each group are presented in Table 2 and Figure 1-2.

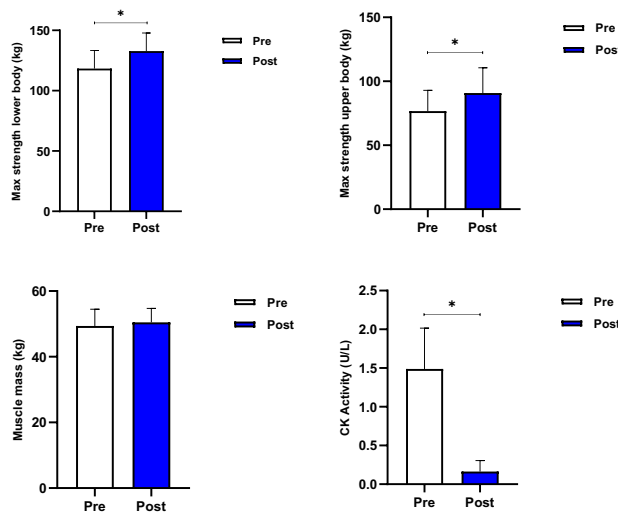


Fig. 1. Assessment of maximum muscle strength, muscle mass, muscle damage at baseline (pre) and week 4 (post) in LLHR group. *Significant at pre ($p < 0.05$). Data are presented as mean $\pm$ SD. p-value was obtained from the results of paired sample t-test analysis. Effect size analysis using Cohen's D

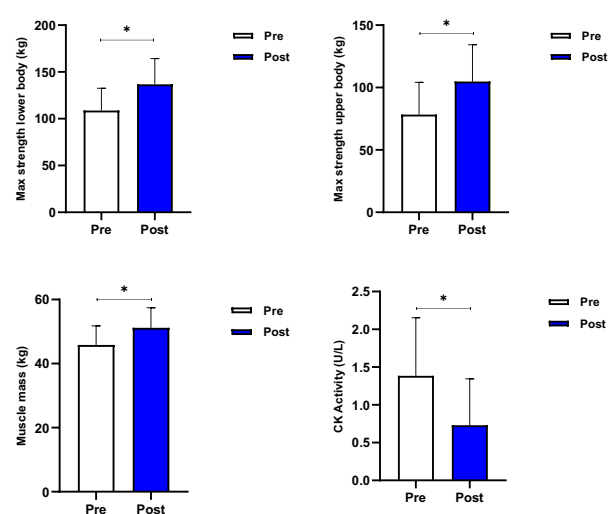


Fig. 2. Assessment of maximum muscle strength, muscle mass, muscle damage at baseline (pre) and week 4 (post) in HLLR group. *Significant at pre ($p < 0.05$). Data are presented as mean $\pm$ SD. p-value was obtained from the results of paired sample t-test analysis. Effect size analysis using Cohen's D

There were significant differences between baseline (pre) and week 4 (post) the intervention of low-load, high-repetition (LLHR) in max strength lower body ($p = 0.001$; effect size (ES): 0.967), max strength upper body ($p = 0.001$; ES: 0.784), and CK Activity ($p = 0.001$; ES: 3.438) ($p < 0.01$). Meanwhile, no differences were observed in muscle mass ($p > 0.05$) (Figure 1).

There were significant differences between baseline (pre) and week 4 (post) the intervention of high-load, low-repetition (HLLR) in max strength lower body ($p = 0.001$; ES: 1.091), max strength upper body ($p = 0.001$; ES: 0.951), muscle mass ($p = 0.001$; ES: 0.875), and CK Activity ($p = 0.031$; ES: 0.941) ($p < 0.05$) (Figure 2).

Table 1. Baseline characteristics of study participants

Parameters	LLHR (n = 14)	HLLR (n = 14)	p-value Independent sample t-test
Age, yrs	19.57 $\pm$ 1.87	19.14 $\pm$ 1.56	0.516
Resting heart rate, bpm	65.72 $\pm$ 8.84	66.79 $\pm$ 6.79	0.722
Oxygen saturation, %	97.29 $\pm$ 1.21	97.50 $\pm$ 1.16	0.636
Systolic blood pressure, mmHg	118.22 $\pm$ 4.63	116.57 $\pm$ 3.96	0.322
Diastolic blood pressure, mmHg	70.36 $\pm$ 5.99	70.86 $\pm$ 7.91	0.852
Body weight, kg	64.14 $\pm$ 6.65	61.43 $\pm$ 7.31	0.314
Height, m	1.71 $\pm$ 0.04	1.69 $\pm$ 0.05	0.224
Body mass index, kg/m ²	21.87 $\pm$ 1.53	21.56 $\pm$ 2.06	0.655
Body fat, %	16.83 $\pm$ 3.11	15.23 $\pm$ 4.38	0.275
Total body water, %	54.61 $\pm$ 3.06	55.34 $\pm$ 3.34	0.548
Bone mass, kg	5.87 $\pm$ 0.69	5.57 $\pm$ 0.91	0.334
Muscle mass, kg	49.39 $\pm$ 5.09	45.81 $\pm$ 5.97	0.100
Max strength lower body, kg	118.26 $\pm$ 14.99	108.79 $\pm$ 23.75	0.221
Max strength upper body, kg	76.71 $\pm$ 16.28	78.33 $\pm$ 25.81	0.844
CK Activity, U/L	1.49 $\pm$ 0.53	1.39 $\pm$ 0.77	0.681

Data are presented as mean $\pm$ SD. p-value was obtained from the results of independent samples t-test analysis

Table 2. Maximum muscle strength, muscle mass, muscle damage assessment at baseline (pre) and week 4 (post).

Parameter	LLHR (n = 14)	HLLR (n = 14)	p-value	Effect Size
Post-Max strength lower body, kg	132.79 ± 15.06	136.82 ± 27.48	0.635	0.181
Post-Max strength upper body, kg	90.87 ± 19.65	104.76 ± 29.59	0.157	0.553
Post-Muscle mass, kg	50.46 ± 4.26	51.17 ± 6.27	0.730	0.132
Post-CK Activity, U/L	0.16 ± 0.14 ^b	0.73 ± 0.62	0.002	1.272
Δ-Max strength lower body, kg	14.54 ± 6.72	28.02 ± 17.37 ^a	0.012	1.024
Δ-Max strength upper body, kg	14.16 ± 7.49	26.43 ± 11.82 ^a	0.003	1.241
Δ-Muscle mass, kg	1.07 ± 3.54	5.36 ± 3.71 ^a	0.004	1.184
Δ-CK Activity, U/L	-1.33 ± 0.53 ^b	-0.66 ± 1.02	0.038	0.828

Δ: Post-Pre. ^aSignificant at LLHR group ($p < 0.05$). ^bSignificant at HLLR group ($p < 0.05$). Data are presented as mean ± SD. p-value was obtained from the results of independent samples t-test analysis. Effect size analysis using Cohen's D

Discussion

This study evaluated the effects of high-load, low-repetition (HLLR) and low-load, high-repetition (LLHR) resistance training protocols on muscle strength, muscle mass, and muscle damage in active adult males. The findings demonstrate that HLLR is superior in increasing maximum muscle strength for both upper and lower extremities, whereas LLHR resulted in significantly reduced muscle damage and meaningful hypertrophic adaptations. These results align with established theories on resistance training and provide insights into optimizing training protocols based on individual goals and recovery needs. The findings of this study are consistent with and extend the results of previous research comparing low-load, high-repetition (LLHR) and high-load, low-repetition (HLLR) resistance training protocols. For example, Ikezoe et al. (2017) found no significant differences between LLHR and HLLR in terms of muscle strength and hypertrophy improvements, suggesting that LLHR can produce similar outcomes to HLLR when repetitions are increased. Our results similarly indicate that LLHR is a viable alternative for promoting hypertrophy while reducing muscle damage, as reflected in lower creatine kinase (CK) levels. Furthermore, the study by Yeom et al. (2023) demonstrated that LLHR induces lower muscle damage markers, such as CK and lactate dehydrogenase (LDH), while still activating key anabolic signaling pathways (e.g., p70S6K1 and 4E-BP1), supporting hypertrophic adaptations. This aligns with our findings that LLHR minimizes muscle damage while eliciting comparable hypertrophic effects. Consistent with Schoenfeld et al. (2015), our study also observed that HLLR produced greater improvements in maximum strength compared to LLHR. This is likely due to HLLR's ability to recruit high-threshold motor units and stimulate neuromuscular adaptations, which is critical for developing maximum force. Similarly, the systematic review by Schoenfeld et al. (2017) highlighted that maximal strength gains are best achieved with high loads, whereas muscle hypertrophy can be achieved across a spectrum of loading ranges. These findings further reinforce our conclusion that HLLR is optimal for strength development, while LLHR provides a safer and more effective alternative for hypertrophy. Bello et al. (2024) also reported that high-load training leads to superior increases in 1-repetition maximum (1RM) strength compared to low-load training, supporting our observation that HLLR is more effective for improving strength outcomes. However,

our findings emphasize that LLHR has the additional advantage of reduced recovery demands, which could be beneficial for specific populations, such as older adults or those in rehabilitation. Additionally, our study complements the findings of Schoenfeld et al. (2017) by confirming that hypertrophic adaptations are not load-dependent, as both LLHR and HLLR protocols produced meaningful muscle mass increases. Overall, our results align with prior studies while providing additional insights into the distinct trade-offs between LLHR and HLLR protocols, particularly in terms of muscle damage and recovery demands. By confirming that both approaches can be effective for different training goals, our study adds to the growing body of evidence supporting the adaptability of resistance training to meet individual needs.

The mechanisms underlying these findings can be explained through distinct physiological pathways and the theoretical basis of resistance training. The superior strength gains observed with HLLR can be attributed to the recruitment of high-threshold motor units, which predominantly engage type II muscle fibers essential for maximum force production (Del Vecchio et al., 2019; Morton et al., 2019). This aligns with the principle of progressive overload, where high-intensity loads promote neuromuscular adaptations and enhanced motor unit synchronization (Pope et al., 2016). Conversely, LLHR leverages metabolic stress to stimulate hypertrophy by activating the Akt/mTOR signaling pathway, promoting protein synthesis, and engaging both type I and type II muscle fibers when performed to failure (Grgic, 2020; McIntosh et al., 2023). This mechanism explains how LLHR achieves meaningful hypertrophic effects with less mechanical tension per repetition, reducing the risk of structural muscle damage. Furthermore, the elevated levels of creatine kinase (CK) observed in the HLLR protocol reflect greater microtrauma induced by heavier loads, which, although beneficial for muscle remodeling, necessitate extended recovery periods to avoid overtraining or injury (Callegari et al., 2017).

The relationship between the protocols and their respective outcomes highlights important trade-offs. For muscle strength, HLLR was significantly more effective due to the high mechanical tension and superior recruitment of type II fibers (Lixandrão et al., 2017). Although LLHR also produced strength gains, its effects were less pronounced, suggesting its potential as a complementary approach for individuals unable to tolerate high loads (Schoenfeld et al., 2015; Evangelou et al., 2021). In terms of muscle mass, HLLR elicited greater increases, consistent with the higher mechanical stress

imposed by heavy loads, while LLHR produced comparable hypertrophy via metabolic stress mechanisms, providing a safer alternative for populations prioritizing joint health or injury prevention (Jenkins et al., 2017). Finally, muscle damage, as indicated by CK levels, was significantly lower in LLHR, further supporting its use for faster recovery and reduced structural stress (Baird et al., 2012).

This study is not without limitations. The intervention period of four weeks may be insufficient to capture the long-term adaptations or cumulative effects of these protocols. The study also focused exclusively on active adult males, which limits the generalizability of the findings to other populations, such as women, older adults, or clinical groups. Additionally, the reliance on CK as the sole marker for muscle damage may not fully represent the complex structural changes occurring at the cellular level, and further studies using imaging or histological techniques are warranted. Lastly, the study did not explore the potential benefits of combining HLLR and LLHR protocols, which may offer complementary advantages for both strength and hypertrophy.

These findings have practical implications for designing resistance training programs. HLLR is optimal for athletes aiming to maximize strength and power, while LLHR is a safer and more sustainable option for individuals prioritizing recovery, joint health, or moderate hypertrophic gains. A combined approach may be beneficial, incorporating HLLR during strength-focused phases and LLHR for hypertrophy and recovery phases, thereby balancing the benefits of both protocols while mitigating their respective limitations.

Future research should investigate the long-term effects of HLLR and LLHR, particularly in diverse populations such as women, older adults, and individuals with pre-existing conditions. Examining the combination of these protocols and their effects on muscle adaptation over extended periods could provide further insights into optimizing training outcomes. Additionally, molecular and structural investigations, such as muscle biopsies and imaging studies, are needed to elucidate the physiological mechanisms underlying these adaptations. By addressing these gaps, future studies could refine resistance training strategies and enhance their applicability across various settings.

This study contributes to the growing body of evidence on resistance training by demonstrating that HLLR is highly effective for maximizing strength and hypertrophy, while LLHR provides comparable benefits with reduced muscle damage and faster recovery. These findings highlight the importance of tailoring resistance training protocols to individual goals, capacities, and recovery demands, thereby optimizing performance outcomes in both athletic and clinical populations.

Conclusions

This study demonstrated that high-load, low-repetition (HLLR) training was more effective for increasing muscle strength and muscle mass, while low-load, high-repetition (LLHR) training reduces muscle damage, as indicated by lower creatine kinase levels. HLLR's superior strength gains result from greater neuromuscular adaptations and high-threshold motor unit recruitment, whereas LLHR offers comparable hypertrophic benefits with less recovery demand, making it suitable for populations prioritizing endurance

or injury prevention. These findings suggest that tailoring resistance training protocols to individual goals—strength versus recovery and joint health—can optimize performance outcomes. Combining HLLR and LLHR may provide a balanced approach to maximize training effectiveness.

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Conflict of Interest

The authors declare that they have no conflict interests in this study.

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Визначення показників максимальної сили м'язів, м'язової маси, пошкодження м'язів у активних дорослих чоловіків після проведення силових тренувань із низьким навантаженням та великою кількістю повторень у поєднанні із високим навантаженням та малою кількістю повторень

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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., 22 джерел.

Мета дослідження. Це дослідження мало на меті оцінити вплив протоколів силових тренувань із високим навантаженням і малою кількістю повторень (HLLR) та низьким навантаженням і великою кількістю повторень (LLHR) на показники сили м'язів, м'язової маси та пошкодження м'язів у дорослих чоловіків, які ведуть активний спосіб життя.

Матеріали та методи. Це квазіекспериментальне дослідження включало 28 активних дорослих чоловіків віком 18-22 років з індексом маси тіла 19-23 кг/м², відібраних для активної участі в дослідженні, які проходили інтервенції з HLLR та LLHR тренувань із частотою 3 рази на тиждень впродовж 4 тижнів. Збір даних проводився шляхом оцінки показників максимальної сили м'язів, м'язової маси та пошкодження м'язів між початковим етапом (до) та завершенням періоду 4 тижнів (після). Для статистичного аналізу застосовано t-критерій для незалежних вибірок з рівнем значущості 95%.

Результати. Достовірні відмінності спостерігалися між інтервенціями HLLR та LLHR тренувань у показниках максимальної сили нижньої частини тулуба (розмір ефекту (ES): 1,024), максимальної сили верхньої частини тулуба (ES: 1,241) та м'язової маси (ES: 1,184) ($p < 0,05$). Водночас встановлено, що активність креатинкінази значно знижена під час виконання LLHR тренувань порівняно з HLLR (ES: 0,828) ($p < 0,05$).

Висновки. Дослідження продемонструвало, що тренування із високим навантаженням і низькою кількістю повторень (HLLR) є ефективнішим з точки зору збільшення м'язової сили і м'язової маси, тоді як тренування із низьким навантаженням і високою кількістю повторень (LLHR) сприяють зменшенню пошкодження м'язів, про що свідчать нижчі рівні креатинкінази.

Ключові слова: максимальна сила м'язів, пошкодження м'язів, м'язова маса, силові тренування.

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Ascertaining the Effectiveness of Strength-Aerobic Combined Exercise in Improving Body Composition among Obese Women: A Randomized Controlled Trial

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Abstract

Background. The novelty of this study is a combination of strength and aerobic exercise, thereby enhancing the benefits of improving body composition. Aerobic exercise is effective for burning calories, which helps to lose fat, while strength exercise facilitates maintaining and building muscle mass.

Objectives. This study aimed to demonstrate that a combination of strength-aerobic exercise can significantly improve the body composition of obese women.

Materials and methods. This study was an experimental randomized controlled trial (RCT) involving 20 participants consisting of obese women who were given the intervention for eight weeks with a frequency of 4x/week. The data collected included a body composition, measured using the TANITA Body Composition Analyzer DC-360 (TANITA Corporation, Inc., IL 60005, USA). The data analysis techniques used were the paired sample t-test, with a significance level of 95 %.

Results. The results obtained indicate that this combined exercise program significantly reduces body weight, body mass index (BMI), fat mass, and body fat percentage ($p < 0.05$). In addition, the program also significantly increases fat-free mass and muscle mass ($p < 0.05$).

Conclusions. The findings showed that a combination of aerobic exercise and endurance led to substantial improvements in body composition in obese women. These results confirm previous studies and provide scientific evidence for including a combination exercise program as part of an obesity management strategy.

Keywords: combined exercise, body composition, healthy lifestyle, obese women.

Introduction

Obesity in women is a growing global health problem. According to a report from the World Health Organization (WHO), in 2020, about 15% of adult women worldwide were obese (BMI ≥ 30) (Li & Chen, 2021). Women who are obese have up to 10 times higher risk of developing diabetes compared to women with normal weight. Obesity in women is not only related to appearance but also poses a significant

danger to physical and mental health (Bakaloudi et al., 2020). The increasing rate of obesity worldwide highlights the urgent need for effective interventions, such as physical activity, a good diet, and psychological support, to mitigate the negative effects (Wang et al., 2022).

Body composition, which shows the ratio of body fat to lean mass (such as muscle, bone, water, and other tissues), is an important indicator of an individual's health (Rejeki et al., 2023). Improving body composition means reducing excess body fat and increasing or maintaining muscle mass, both of which provide significant benefits for physical and mental health (Pekas et al., 2020). Amid rising global obesity rates, especially among women, the development of effective strategies to improve body composition is becoming increasingly important (Mpampoulis et al., 2024).

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Aerobic exercise, consisting of sustained moderate to high-intensity activities such as running, cycling, or swimming, offers various benefits to the body (Ashadi et al., 2024). Aerobic exercise can enhance calorie burning, which contributes to weight loss, and improve cardiovascular capacity by increasing the heart and lungs' efficiency in delivering oxygen to muscles, supporting heart health (Jones et al., 2020). This exercise modality is also effective in reducing body fat percentage, including visceral fat, which is strongly associated with metabolic disease risks. Additionally, aerobic exercise improves insulin sensitivity and regulates stress hormones such as cortisol, reducing fat accumulation (Youssef et al., 2022). However, aerobic exercise alone has limitations—it does not significantly increase muscle mass, a critical factor in boosting basal metabolism (Kysel et al., 2023). Weight loss due to aerobic exercise without incorporating strength training may risk muscle mass loss (Zhang et al., 2023).

Strength exercises, such as weightlifting or bodyweight training, aim to strengthen and increase muscle mass (Valenzuela et al., 2021). These exercises enhance muscle mass and basal metabolic rate, allowing for higher calorie expenditure even at rest through the excess post-exercise oxygen consumption (EPOC) effect (Versic et al., 2021). Strength training also improves posture and physical function by strengthening supporting muscles that help prevent injury (Atakan et al., 2021). Furthermore, it improves glucose regulation by increasing insulin sensitivity, as muscle mass serves as the primary reservoir for glucose storage (Domingues et al., 2024). Despite these benefits, strength training burns fewer calories during exercise compared to aerobic activities and is less effective in improving cardiovascular health (Oh & Lee, 2023).

Given the complementary benefits of aerobic and strength exercises, integrating these modalities has emerged as a highly effective approach for improving body composition. Aerobic exercise facilitates fat loss by increasing calorie burn, while strength training preserves and builds muscle mass, ensuring weight loss comes from fat rather than lean tissue (Jamka et al., 2021). Strength training further enhances basal metabolism, allowing for sustained calorie burning even after an aerobic session (Park et al., 2020). The combined approach is not only effective for heart health but also strengthens the body for daily physical activities (Pippi et al., 2022).

This integrated method has a superior long-term effect, enabling more sustainable weight loss compared to relying on a single exercise type. Studies that focus solely on one type of exercise often overlook the synergistic benefits of combining both aerobic and strength exercises, which have been proven to be more effective in improving overall body composition (Manojlović et al., 2021). Therefore, a dual approach should be emphasized in fitness strategies, especially for populations with obesity, such as women (Coelho-Júnior et al., 2020).

The aim of this study is to demonstrate that the combination of aerobic and strength exercise can significantly improve the body composition of obese women. This research offers an important contribution to the global community by presenting a practical, evidence-based approach to managing obesity. Furthermore, the findings underscore the importance of incorporating both aerobic and strength training into exercise programs, benefiting not

only individuals but also contributing to public health efforts worldwide.

Materials and Methods

Study Design

This study was an experimental randomized controlled trial (RCT). The purpose of this study was to compare combination of strength and aerobic exercise in the experimental group that received the intervention and the control group that did not receive the intervention. A total of 20 people were divided into two groups: a control group (Control) consisting of 10 people without intervention and 10 other participants who were given combination of strength and aerobic exercise interventions (Exercise). The study began by disseminating information about open recruitment for research samples through social media. The sample was selected based on predetermined criteria, namely: young adult women aged 20-30 years, inactive in exercise, with a BMI above 28 kg/m², and willing to participate in an exercise program for 8 weeks. The training was carried out on a scheduled basis with the guidance of the research team and instructors every Monday, Tuesday, Wednesday, Thursday, and Saturday. Details of the training program are presented in Table 1.

Data Collection Techniques

Body fat measurements will be carried out using TANITA Body Composition Analyzer DC-360 (TANITA Corporation, Inc., IL 60005, USA) twice, before and one day after the four-week intervention period. The height of the subjects will be measured using a portable stadiometer Seca 213 (Seca 213, Hammer Steindamm 3-25 22089, Hamburg Germany).

Data Analysis Techniques

The data analysis in this study will use Shapiro-Wilk to test normality. The paired sample t-test was applied to evaluate the differences in each group, while the independent sample t-test was to analyze the differences between groups. The applied significance level was a 95%, and the data will be presented as an mean $\pm$ standard deviation (SDs). Effect size was assessed using Cohen's D analysis.

Results

The results of the analysis of participant characteristics are presented in Table 2. Table 2 shows no significant differences in age, body mass index, body composition, resting heart rate, and blood pressure, and oxygen saturation observed all analysis results show $p \geq 0.05$ (Table 2). Meanwhile, the results of body composition assessments between pre and post exercise are presented in Figure 1.

Based on Figure 1, it shows that there are significant differences between baseline (pre) and weeks 8 (post) in weight ($p = 0.001$; ES = 1.337), BMI ($p = 0.001$; ES = 0.651), PBF ($p = 0.001$; ES = 0.896), FM ($p = 0.001$; ES = 0.423), FFM ($p = 0.001$; ES = 0.524), and MM ($p = 0.001$; ES = 0.494) in the exercise group. Meanwhile, in the control group no significant differences were observed ($p > 0.05$). The results of the analysis of differences between groups are presented in Table 3.

Table 1. The training program of strength aerobic combined exercise

Weeks	Strength-aerobic combined exercise group	Control group
Week – 1	Moderate-intensity continuous training The intensity was done at 60 % of maximum heart rate for 30 minutes Total body strength training The intensity was done at 60 % of 1 repetition maximum (1RM) with a 4 sets of 12-15 repetitions Warming up and cooling down are each done for 5 minutes at an intensity of 50 % HRmax.	Without exercise intervention
Week – 2	Moderate-intensity continuous training The intensity was done at 60 % of maximum heart rate for 30 minutes Total body strength training The intensity was done at 60 % of 1 repetition maximum (1RM) with a 4 sets of 12-15 repetitions Warming up and cooling down are each done for 5 minutes at an intensity of 50 % HRmax.	Without exercise intervention
Week – 3	Moderate-intensity continuous training The intensity was done at 65 % of maximum heart rate for 30 minutes Total body strength training The intensity was done at 65 % of 1 repetition maximum (1RM) with a 4 sets of 12-15 repetitions Warming up and cooling down are each done for 5 minutes at an intensity of 50 % HRmax.	Without exercise intervention
Week – 4	Moderate-intensity continuous training The intensity was done at 65 % of maximum heart rate for 30 minutes Total body strength training The intensity was done at 65 % of 1 repetition maximum (1RM) with a 5 sets of 12-15 repetitions Warming up and cooling down are each done for 5 minutes at an intensity of 50 % HRmax.	Without exercise intervention
Week – 5	Moderate-intensity continuous training The intensity was done at 65 % of maximum heart rate for 35 minutes Total body strength training The intensity was done at 65 % of 1 repetition maximum (1RM) with a 5 sets of 12-15 repetitions Warming up and cooling down are each done for 5 minutes at an intensity of 50 % HRmax.	Without exercise intervention
Week – 6	Moderate-intensity continuous training The intensity was done at 65 % of maximum heart rate for 35 minutes Total body strength training The intensity was done at 65 % of 1 repetition maximum (1RM) with a 5 sets of 12-15 repetitions Warming up and cooling down are each done for 5 minutes at an intensity of 50 % HRmax.	Without exercise intervention
Week - 7	Moderate-intensity continuous training The intensity was done at 70 % of maximum heart rate for 35 minutes Total body strength training The intensity was done at 70 % of 1 repetition maximum (1RM) with a 5 sets of 12-15 repetitions Warming up and cooling down are each done for 5 minutes at an intensity of 50 % HRmax.	Without exercise intervention
Week – 8	Moderate-intensity continuous training The intensity was done at 70 % of maximum heart rate for 40 minutes Total body strength training The intensity was done at 70 % of 1 repetition maximum (1RM) with a 6 sets of 12-15 repetitions Warming up and cooling down are each done for 5 minutes at an intensity of 50 % HRmax.	Without exercise intervention

Table 2. Baseline characteristics of study participants

Variable	Control (n = 10)	Exercise (n = 10)	p-value Independent sample t-test
Age (years)	23.30 ± 1.34	23.20 ± 1.48	0.876
Resting heart rate (beats/min)	74.20 ± 4.35	75.55 ± 7.61	0.632
Systolic blood pressure (mmHg)	115.06 ± 3.43	116.05 ± 2.89	0.494
Diastolic blood pressure (mmHg)	75.20 ± 2.87	75.05 ± 4.38	0.929
Oxygen saturation (%)	99.00 ± 0.82	99.10 ± 0.88	0.795
Height (m)	1.56 ± 0.05	1.55 ± 0.04	0.756
Weight (kg)	74.46 ± 6.79	74.05 ± 7.03	0.896
Body mass index (kg/m ²)	30.43 ± 1.39	30.54 ± 2.26	0.891
Percentage of body fat (%)	34.70 ± 3.11	34.79 ± 1.91	0.939
Fat mass (kg)	26.45 ± 5.21	25.15 ± 3.82	0.533
Free fat mass (kg)	35.43 ± 5.96	33.89 ± 3.12	0.479
Muscle mass (kg)	25.93 ± 2.05	24.71 ± 2.45	0.243

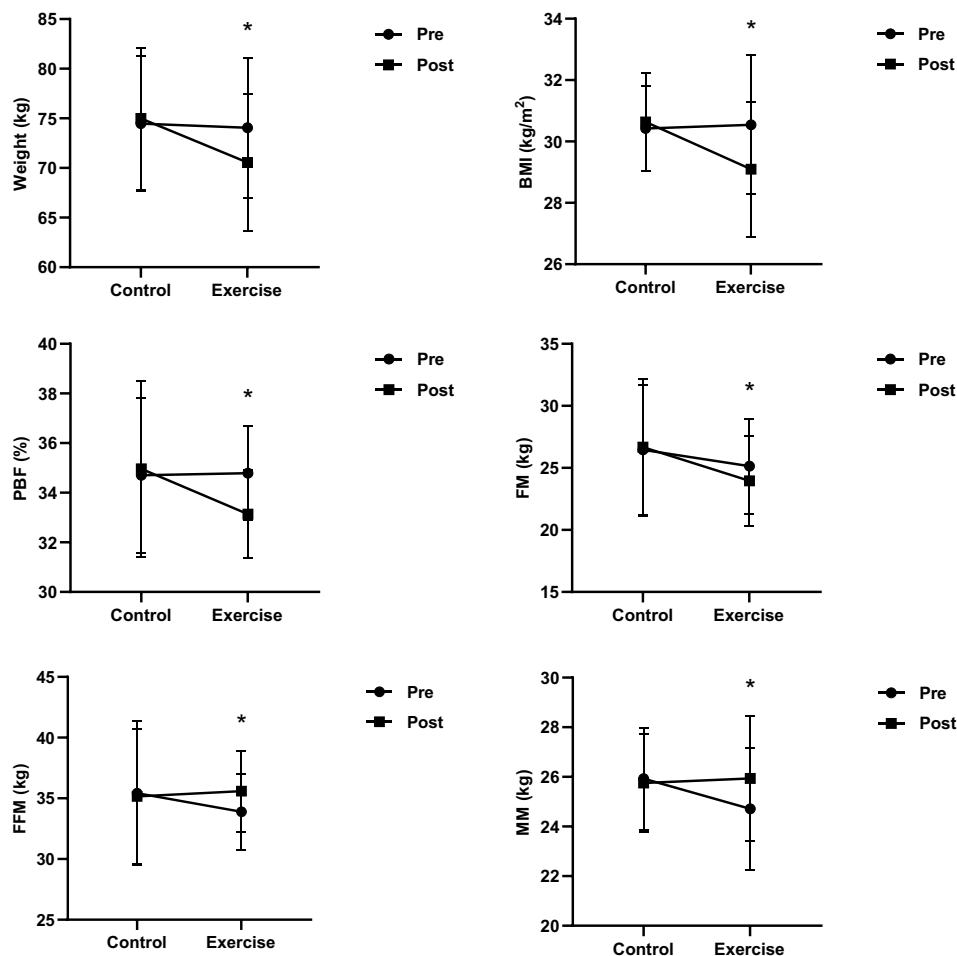


Fig. 1. Assessment of weight, body mass index (BMI), percentage of body fat (PBF), fat mass (FM), fat-free mass (FFM), and muscle mass (MM) baseline (pre) and weeks 8 (post) in each group. The data was presented as mean ± standard deviation (SDs). *Significantly different from pre in exercise group p < 0.001.
ES: Effect size. p-value was obtained by paired sample t-test

Table 3. Assessment of weight, BMI, PBF, FM, FFM, and MM baseline (pre) and weeks 8 (post) between groups

Variable	Control (n = 10)	Exercise (n = 10)	p-value	Effect size
Post-Weight (kg)	74.98 ± 7.15	70.55 ± 6.86	0.175	0.632
Post-BMI (kg/m ²)	30.64 ± 1.59	29.09 ± 2.19	0.089	0.804
Post-PBF (%)	34.97 ± 3.55	33.14 ± 1.77	0.163	0.651
Post-FM (kg)	26.67 ± 5.52	23.95 ± 3.64	0.211	0.581
Post-FFM (kg)	35.15 ± 5.52	35.59 ± 3.34	0.832	0.096
Post-MM (kg)	25.76 ± 1.99	25.94 ± 2.52	0.861	0.079
Δ-Weight (kg)	0.52 ± 1.44	-3.50 ± 0.48 ^a	0.000	3.732
Δ-BMI (kg/m ²)	0.21 ± 0.59	-1.45 ± 0.21 ^a	0.000	3.727
Δ-PBF (%)	0.27 ± 0.67	-1.65 ± 0.26 ^a	0.000	3.767
Δ-FM (kg)	0.22 ± 0.52	-1.19 ± 0.24 ^a	0.000	3.513
Δ-FFM (kg)	-0.28 ± 0.71	1.69 ± 0.32 ^a	0.000	3.623
Δ-MM (kg)	-0.17 ± 0.51	1.23 ± 0.18 ^a	0.000	3.634

The data was presented as mean ± standard deviation (SDs). ^aSignificantly different from control group $p < 0.001$. p-value was obtained by paired sample t-test

Discussion

The study demonstrated the significant impact of combined strength and aerobic exercise on body composition in obese women. The results indicate that this combined exercise program significantly reduces body weight, body mass index (BMI), fat mass, and body fat percentage while increasing muscle mass and fat-free mass (FFM). These findings underline the effectiveness of combination exercise programs in achieving a healthier body composition.

The results align with and extend prior research on the effects of combined aerobic and strength exercises on body composition. For instance, Oh and Lee (2023) found that an 8-week combined exercise program significantly reduced body fat percentage, triglyceride levels, and leptin levels in middle-aged women with obesity. They also observed that moderate-intensity aerobic exercise during combination training yielded slightly better outcomes for lipid profiles than vigorous-intensity aerobic exercise. Similarly, Cicek and Singin (2023) showed that 10 weeks of either aerobic or strength of life significantly improved BMI, fat mass, and quality of life (QoL) sub-dimensions such as physical and psychological health. These findings reinforce the results of the present study, emphasizing the holistic benefits of combined exercise programs, particularly their ability to enhance body composition and overall well-being.

Aerobic and strength exercises, especially when combined, have long been recognized as effective strategies for addressing obesity (Pojednic et al., 2022). The dual approach is superior to performing either exercise alone in reducing fat mass (Jamka et al., 2021). The primary mechanism involves increased energy expenditure and metabolic efficiency, with aerobic exercise directly contributing to calorie burning and strength training promoting muscle mass maintenance or growth (Makiel et al., 2023). Notably, an increase in FFM, as observed in this study, is associated with a higher basal metabolic rate, which facilitates more effective weight management (Ahn & Kim, 2022).

This study's findings are consistent with evidence that adding strength training to an aerobic exercise program enhances fat reduction and increases FFM. Strength training stimulates muscle protein synthesis, which aids in improving body composition by increasing muscle mass and reducing fat (Despeghel et al., 2021). Furthermore, the decrease in fat mass observed in this study aligns with metabolic adaptations supported by hormones such as leptin and adiponectin, which are influenced by consistent physical activity (Garcia-Roca et al., 2024). The increase in FFM observed in this study highlights the role of strength training in promoting muscle growth, contributing to improved metabolic health and overall physical strength.

Combination exercises impact body composition through multiple mechanisms. Aerobic exercise increases fat oxidation and insulin sensitivity, which reduces fat accumulation, while strength training enhances muscle hypertrophy and metabolic activity (Lee et al., 2024). These complementary effects underscore the importance of combining aerobic and strength exercises to achieve optimal results. This approach not only reduces fat mass but also increases FFM, which has profound implications for long-term metabolic health and physical functionality.

The results have important implications for obesity management, particularly in women. Considering that obesity in women is often linked to hormonal and metabolic changes, combined exercise programs provide an effective strategy for achieving weight loss and improving overall health (Masouleh et al., 2021; Tan et al., 2023). To maximize benefits, the duration, intensity, and frequency of exercise programs must be tailored to individual conditions (Białkowski et al., 2024). For instance, Bagheri et al. (2023) recommend exercising three times per week for 60 minutes per session over 12 weeks to achieve significant results. This regimen aligns with the current study's findings, which support moderate-intensity aerobic exercise combined with strength training targeting major muscle groups for optimal outcomes (Bakaloudi et al., 2020; Oh & Lee, 2023).

However, this study has certain limitations. The sample size was relatively small and included only young adult women with sedentary lifestyles, limiting the generalizability of the findings. Previous research suggests that older women and other demographic groups may exhibit different responses to combination exercise programs due to variations in hormonal, metabolic, and lifestyle factors (Méndez-Hernández et al., 2022). Additionally, the short duration of the intervention may not capture the long-term effects of combined exercise programs. Future research should explore the sustainability of benefits over extended periods and assess the effects of different exercise intensities and frequencies to refine individualized exercise prescriptions (García-Roca et al., 2024).

Studies on the combination of aerobic and strength exercise are essential as a preventive measure against global obesity. They offer practical, scalable solutions with broad health benefits, including improved metabolic health, enhanced physical strength, and better quality of life. Furthermore, the integration of these findings into public health policies could contribute to addressing the global obesity epidemic. Future research should also consider including quality-of-life assessments and additional health metrics to capture the comprehensive benefits of combined exercise programs.

Conclusion

The study highlighted that combining aerobic and strength exercises effectively enhances body composition in obese women. These findings support earlier studies and offer scientific backing for including combination exercise programs in strategies for managing obesity. Therefore, the development of programs tailored to individual needs is essential to improve the success of interventions and long-term health.

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Conflict of Interest

The authors declare that they have no competing interests in this study.

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З'ясування ефективності поєднання силових та аеробних вправ щодо покращення композиції тіла у жінок з ожирінням: Рандомізоване контрольоване дослідження

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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., 2 рис., 22 джерел.

Історія питання. Наукова новизна цього дослідження полягає у вивченні поєднання силових та аеробних вправ, застосування яких посилює позитивний вплив на поліпшення компонентного складу тіла. Виконання аеробних вправ є ефективним з точки зору спалювання калорій, що допомагає позбутися жирових відкладень, тоді як силові вправи сприяють підтримці та нарощуванню м'язової маси.

Мета дослідження. Це дослідження мало на меті продемонструвати, що поєднання силових та аеробних вправ може суттєво покращити композицію тіла жінок з ожирінням.

Матеріали та методи. Проведено експериментальне рандомізоване контрольоване дослідження (РКД) за участю 20 жінок з ожирінням, які проходили інтервенцію протягом восьми тижнів із частотою 4 рази на тиждень. Збір даних включав визначення складу тіла за допомогою аналізатора складу тіла TANITA DC-360 (TANITA Corporation, Inc., IL 60005, США). Методи аналізу даних передбачали застосування t-критерію для парних вибірок з рівнем значущості 95%.

Результати. Отримані результати вказують на значне зниження маси тіла, індексу маси тіла (ІМТ), жирової маси та відсоткового вмісту жиру в організмі ($p < 0,05$) завдяки застосуванню комбінованої програми тренувань ($p < 0,05$). Крім того, застосування зазначеної програми забезпечує достовірне підвищення показників безжирової маси та м'язової маси ($p < 0,05$).

Висновки. Результати дослідження показали, що поєднання аеробних вправ і витривалості призводить до суттєвого поліпшення композиції тіла у жінок з ожирінням. Вказані результати підтверджують дані попередніх досліджень і надають наукові докази щодо включення комбінованої програми тренувань як частини стратегії боротьби з ожирінням.

Ключові слова: комбіновані фізичні вправи, композиція тіла, здоровий спосіб життя, жінки з ожирінням.

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Review Article

Analyzing Research Trends on High Intensity Interval Training and Oxidative Stress: A Bibliometric Analysis (2003-2024)

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Abstract

Background. Exercise-induced oxidative stress, often resulting from high-intensity interval training (HIIT), can cause short-term declines in performance due to alterations in cellular and DNA function. Therefore, oxidative stress markers have gained increased attention for their potential role in reducing risks and improving individual performance.

Objectives. This study aimed to assist researchers and practitioners in grasping current research trends and exploring future research directions in the field of oxidative stress and HIIT.

Materials and methods. This paper presents a comprehensive bibliometric overview and visualization of research on oxidative stress in HIIT, analyzing 192 publications from the Scopus database. Scopus was chosen for data extraction due to its prominence as Elsevier's citation database, high-quality peer-reviewed works, and four metrics: h-index, CiteScore, SCImago Journal Rank (SJR), and Source Normalized Impact per Paper (SNIP).

Results. By employing various visualization tools to analyse influential authors, organisations, and keywords, the paper identifies leading publications and key research clusters related to oxidative stress in HIIT.

Conclusions. Through performing citation and reference co-citation analyses, the study highlights central research topics and emerging trends pertaining to oxidative stress in HIIT.

Keywords: high-intensity interval training, oxidative stress, exercise, bibliometrics.

Introduction

High-intensity interval training (HIIT) is recognized as a highly effective and time-efficient method for enhancing cardiorespiratory and metabolic functions, significantly contributing to optimizing physical performance across different domains (Sarkar et al., 2021). In general, High-intensity interval training offers several benefits. It is distinguished by short periods of vigorous physical activity (approximately 85–90% of $\text{VO}_{2\text{max}}$), usually lasting one to four minutes, followed by intervals of lower-intensity exercise or rest (Alansare et al., 2018). This training program was rated top in the health and fitness trends because of its time-saving nature (Petersen et al., 2016; Thompson, 2018). Moreover, this methodology capitalizes on the efficiency of workout time and contributes to a broad spectrum of fitness improvements, embodying a multifaceted approach

to physical conditioning (Laursen and Jenkins, 2002). HIIT is a promising alternative to traditional endurance training, achieving similar or better improvements in physiological, performance, and health outcomes across both healthy and diseased populations (Gibala et al., 2008). It also helps manage oxidative stress, a key factor in cellular damage and overall health, highlighting its effectiveness in boosting fitness, supporting cellular health, and fostering resilience.

Oxidative stress represents a fundamental biological phenomenon characterized by an imbalance between the generation of reactive oxygen species (ROS) and the organism's capacity to neutralize them through antioxidant defenses (Sies, 2020). This imbalance can lead to significant cellular damage, affecting proteins, lipids, and DNA. Such damage is implicated in various health conditions, including chronic diseases and the aging process (Oxidative Stress, MODRN, n.d.). In 1956, Denham Harman introduced the free radical theory of aging, highlighting the detrimental effects of free radicals (Harman, 1956). According to this theory, the production of ROS, which are oxygen-containing

molecules that can form free radicals, is a byproduct of metabolic processes. Although ROS are naturally produced during normal metabolism (Forsberg et al., 2001), excessive accumulation of these species can inflict harm on cellular macromolecules, including proteins, DNA, and lipids (Gutteridge et al., 1996; Halliwell, 1996). To counter such damage, the body relies on an array of antioxidants—metabolites and enzymes that counteract the detrimental effects of ROS by neutralizing free radicals, thereby safeguarding cellular components (Pham-Huy et al., 2008; Cooper et al., 2002).

Understanding the relationship between oxidative stress and high-intensity interval training (HIIT) is critical because HIIT is known to reduce oxidative stress and enhance overall health outcomes. Bibliometric analysis, which involves the statistical examination of research publications, can provide valuable insights into the evolving body of knowledge on this topic. Given the increasing volume of research on both oxidative stress and HIIT in recent years, there is a pressing need for a comprehensive review. The current study aims to address this gap by conducting a bibliometric analysis using the Scopus database, summarizing and evaluating the research landscape concerning oxidative stress and HIIT.

The structure of the paper is organized as follows: Part 2 outlines the study methods, Part 3 presents the analysis results, Part 4 provides an in-depth discussion of the results, and Part 5 presents the study's conclusion and provides guidance for future research.

Material and Methods

Development of Research Questions

This study's main objective was to conduct a bibliometric analysis of HIIT and Oxidative Stress manuscripts that were published in the Scopus database. Some research questions have been formulated to help achieve this goal. Table 1 shows these questions and their significance.

Table 1. Research questions and their importance

Research Questions (RQ)	Importance
RQ1: What is the annual Trend oxidative stress and HIIT?	It is important to determine the yearly volume of publications on oxidative stress and HIIT, as this can help predict future trends.
RQ2: Which author contributed more to oxidative stress and HIIT research?	It would assist researchers in locating specific studies, authors, and their link for conducting high-quality research on oxidative stress and high-intensity interval training.
RQ3: Which Subject area published more research work on oxidative stress and HIIT?	It will help to identify the Main Subject area on oxidative stress and high-intensity interval training in various areas and types of documents.
RQ4: What is the topmost publication with citations for oxidative stress and HIIT?	It would be beneficial for researchers studying oxidative stress and high-intensity interval training to carefully select conferences, universities, and journals to publish their research work. This decision could potentially impact the future citations of their papers.
RQ5: Which are the leading countries in the publication of oxidative stress and HIIT?	It would help researchers and practitioners understand which countries are focusing more on oxidative stress and high-intensity interval training. This will enable them to contribute their research work in those countries for future publications.
RQ6: What is the keyword network of oxidative stress and HIIT?	It will be an easy method of searching for future research. This will assist researchers in pinpointing future research directions.

Data Extraction

Selecting the appropriate search engine for data extraction is essential. In this study, Scopus was chosen for data extraction due to its prominence as Elsevier's citation database, high-quality peer-reviewed work, and four metrics: h-index, Cite Score, SCI Imago Journal Rank (SJR), and Source Normalized Impact per Paper (SNIP) (Sidhu et al., 2020).

The total number of papers published in Scopus in the field of oxidative stress and HIIT were 229. The following method were used to search for publication topic word = ("High Intensity Interval Training" OR "High-Intensity Interval Training" OR "High Intensity Intermittent Training" OR "High-Intensity Intermittent Training" OR "High Intensity Intermittent Exercise" OR "High-Intensity intermittent Exercise" OR "High Intensity Interval Exercise" OR "High-Intensity Interval Training" AND "Oxidative Stress" OR "Oxidative Stresses" OR "Oxidative Damage") time period = 2003 to 2024. In our review of previous bibliometrics literature (You et al., 2021) we only included articles and reviews that were written in English. Therefore, any works not in English were excluded from our analysis.

Table 2. Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Language	English	Other than English
Time period	2003-2024	<2003
Literature	Articles, Reviews	Book chapter, short survey, Note and Editorial
Publication stage	Final	Article in press
Subjects	Human	Animals

Analysis Tool

The study used VOSviewer to analyze literature on the relationship between oxidative stress and HIIT. The

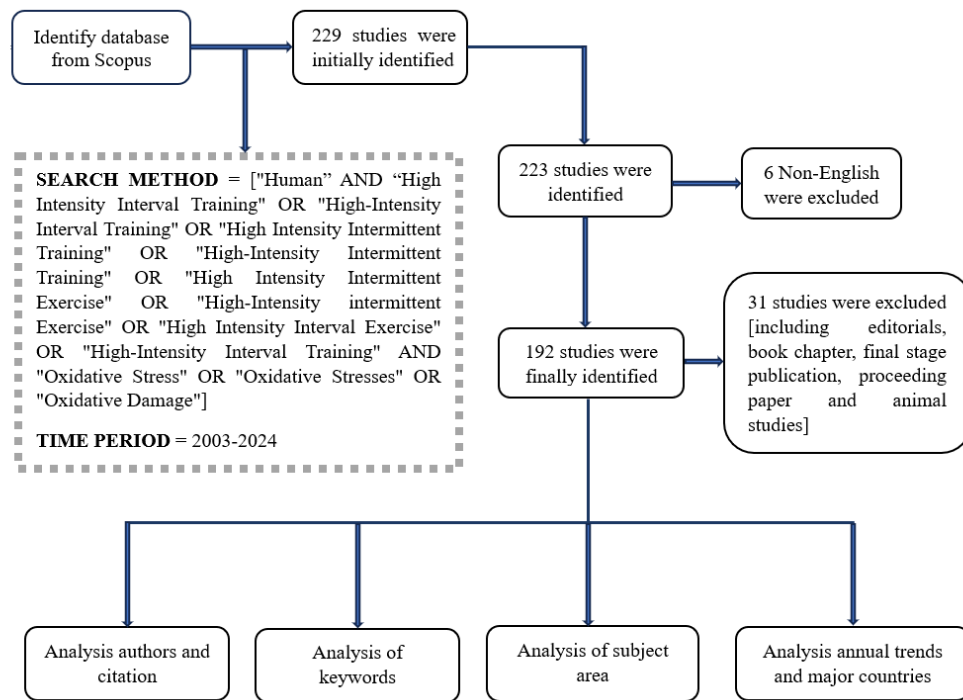


Fig. 1. Flow Diagram with the stages of the methodology for selecting manuscripts

visualizations revealed key authors, influential publications, and key research areas. VOSviewer also analyzed citations to identify the most frequently cited papers. The analysis helped identify critical developments, influential studies, and emerging research directions in the field. The visualizations provided a clear understanding of the major themes and focus areas within the research. Overall, VOSviewer's analytical capabilities provided valuable insights into the evolving research landscape of oxidative stress and HIIT.

Results

Citation Analysis

The study "Analyzing Research Trends on HIIT and Oxidative Stress: A Bibliometric Analysis (2000-2023)" provides a comprehensive analysis of research trends, including annual publications, key referenced documents,

influential authors, major journals, and prominent countries in the area.

Table 3 presents a summary of the top 10 most cited publications in the field of high-intensity interval training (HIIT) and oxidative stress. This information provides an overview of the leading publications across various journals and addresses the research gaps concerning oxidative stress and HIIT. The study conducted by Gibala and McGee (2008) has received the most citations, totalling 523, in the Journal of Exercise and Sports Sciences Review. The study concluded that HIIT can significantly enhance skeletal muscle oxidative capacity, endurance performance, and metabolic control during aerobic-based exercise, even with just six sessions over two weeks. Ramos et al. (2015) performed a systematic review and meta-analysis comparing HIIT to moderate-intensity interval training on vascular function; this publication has garnered 488 citations and is published in Sports Medicine. The paper titled "The Effects of High-

Table 3. Analysis of citations among various authors

S. No.	Authors	Source/Journal	Total Citations
1	Gibala (2008)	Exercise and sports sciences review	523
2	Ramos (2015)	Sports Medicine	488
3	Jelleyman (2015)	Obesity Review	409
4	Papadopoulou (2020)	Nutrients	217
5	Malinowski (2019)	Nutrients	157
6	Mahalakshmi (2020)	International Journal of Molecular Science	143
7	Bogdanis (2013)	Food and Chemical Toxicology	135
8	Flockhart (2021)	Cell Metabolism	119
9	Hull (2020)	The Lancet Respiratory Medicine	117
10	Huang (2019)	Nutrients	105

Intensity Interval Training on Glucose Regulation and Insulin Resistance: A Meta-Analysis” by Jelleyman et al. (2015) has received 409 citations in the *Obesity Review Journal*. The study by Papadopoulou (2020), published in *Nutrients*, received 217 citations. Additionally, Papadopoulou’s (2020) study on intermittent fasting and cardiovascular disorders, also published in *Nutrients*, has gathered 157 citations. Furthermore, the study conducted by Mahalakshmi et al. (2020), published in the *International Journal of Molecular Sciences*, received 143 citations.

Likewise, Bogdanis et al. (2013) investigated the effects of short-term HIIT on oxidative stress and antioxidants in healthy individuals. Their research received 135 citations and is published in the *Journal of Food and Chemical Toxicology*. Additionally, research by Flockhart et al. (2021) received a total of 119 citations and is published in *Cell Metabolism*. Furthermore, the study by Hull et al. (2020), published in *The Lancet Respiratory Medicine*, received 117 citations. Huang et al. published a scholarly article entitled “The Beneficial Effects of *Lactobacillus plantarum* PS128 on High-Intensity, Exercise-Induced Oxidative Stress, Inflammation, and Performance in Triathletes” in the *Journal of Nutrients*, which received a total of 105 citations. This citation analysis highlights the most impactful research and authors in the field of high-intensity interval training and oxidative stress.

Yearly Publications

The graph depicted in Figure 2 illustrates the annual number of publications on high-intensity interval training and oxidative stress that have been published or indexed in Scopus from 2003 to 2024. Between 2003 and 2014, the number of yearly publications ranged from 0 to 4, indicating minimal emphasis on this topic. The number of publications has shown a clear upward trend since 2015, with a range of 3 to 24 from 2015 to 2020. In 2021 and 2022, there was a slight reduction, with 22 and 21 publications respectively. However, in 2023, there was a significant increase, reaching a peak of 35. In 2024, there is a positive trend, with 18 articles published so far, and it is expected to approach

the publication numbers of 2023. Overall, the data shows that the number of publications has been increasing over the last 20 years, although there are annual variations in the publication numbers.

Subject Area Analysis

Figure 3 depicts the prominent subject area in the field of HIIT and Muscle Damage. The fields of Medicine and Biochemistry have the highest number of publications, with 133 and 79, respectively. This indicates that the medical field is particularly prominent in the study of HIIT and oxidative stress. The field of Nursing and Health Profession contributed 23 and 22 publications respectively, showing a valuable focus on health parameters of an individual. The subject area of Agricultural and Biological Sciences is having less publications amounted by 17. Furthermore, subjects contribute little less are Chemistry, Pharmacology, Toxicology and Pharmaceuticals, and Neuroscience documents amounted 8, 8, and 7 respectively, indicating less emphasis on the neuron and biochemical parameters.

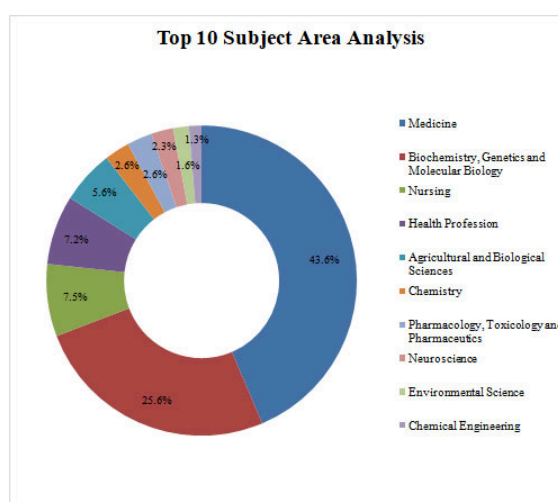


Fig. 3. Subject area analysis

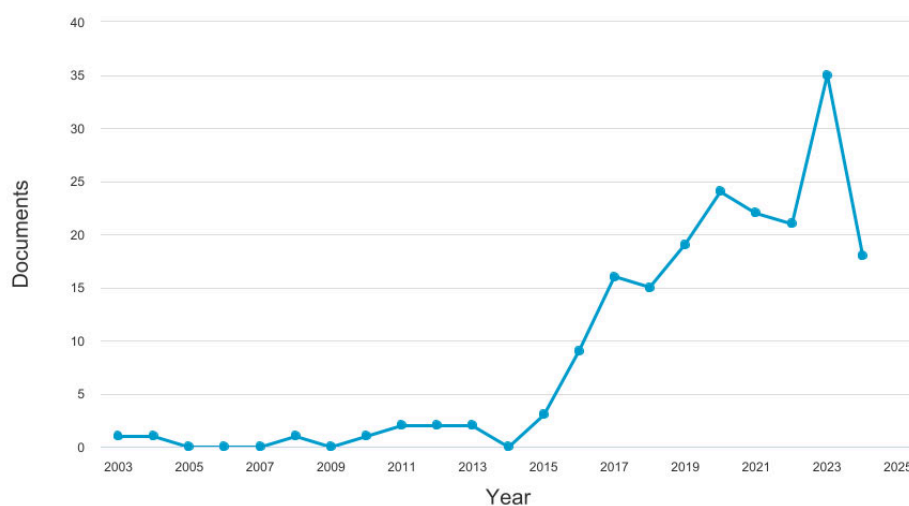


Fig. 2. Yearly publications

The field of Environmental Science and Chemical Engineering each contributed 5 documents, suggesting that researchers from diverse fields are also being involved in the study of HIIT and Oxidative Stress. In general, the data indicate that HIIT and oxidative stress are interdisciplinary topics involving multiple domains. A thorough understanding of this concept requires integrating knowledge from various fields.

Co-occurrence of Keywords

Figure 4 demonstrates keyword clustering based on co-occurrence. An appropriate method was deployed to analyze the co-occurrence of keywords related to HIIT and oxidative stress. A total of 3056 keywords were extracted from 192 research articles, with 346 keywords occurring a minimum of 5 times. The selected keywords were classified into 4 clusters. Cluster one consists of 111 items. In general, a larger circle indicates more frequent use of that keyword in scholarly work. The study reveals that keywords such as “oxidative stress”, “High intensity interval training”, “tumor necrosis factor”, “human”, “exercise intensity”, “male”, and “metabolism” are more frequently used in comparison to “obesity”, “body mass”, “insulin”, and “dietary supplement”. Future research should explore these keywords and current trends in relation to HIIT and oxidative stress, aiming to provide a more comprehensive understanding.

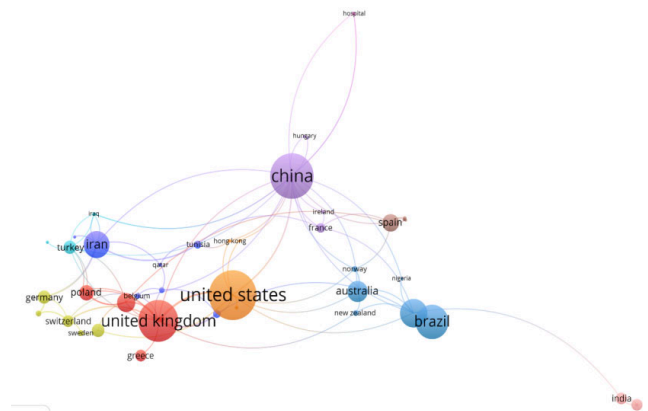


Fig. 5. Top most contributed countries

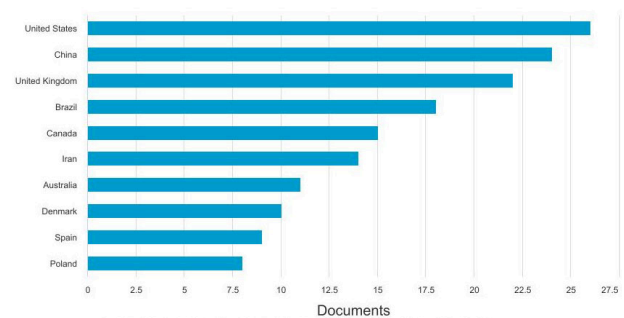


Fig. 6. No. of document published by top 10 countries

investments in sports sciences and research. These nations are characterized by advanced technology and substantial research investments, which have positioned them at the top of this research area.

Top Authors

Figure 7 displays the top authors and their publications in HIIT and oxidative stress. The top seven authors each have published four articles, reflecting a high level of competition within the field. Among them, the leading author is Candow, D.G., who has published four papers, followed by Davison, G.W., with an equal number of publications. Additionally, Dehghan, P., Levinger, I., Parker, L., Shaw, C.S., and Stepto, N.K. have each contributed four papers. Bangsbo, J. has published three articles, closely followed by Chatzinikolaou, A. and Deli, C.K., each with three publications. Figure 8 illustrates the clusters of authors who are actively involved in this research area, highlighting their significant contributions to the field of high-intensity interval training and oxidative stress.

Discussion

This study aims to analyze research collaboration and associations in HIIT and oxidative stress from 2003 to 2024 using the Scopus database. It extracts 192 publications and 5,555 citations, including studies involving human subjects, review articles, and original research articles, from 2003 to 2024.

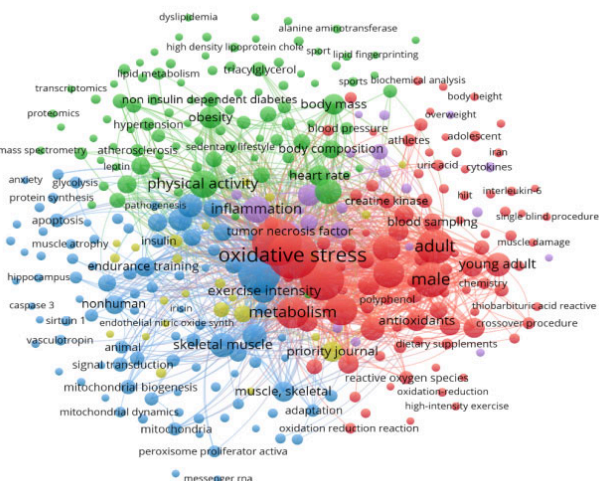


Fig. 4. Co-occurrence of keywords

Country Analysis

From 2003 to 2024, the United States ranked highest in HIIT and oxidative stress publications, with 26 documents, attributed to its advanced technology and research infrastructure in sports sciences, according to Figures 5 and 6. China follows closely with 24 documents, reflecting significant advancements in research. The United Kingdom and Brazil have published 22 and 18 documents, respectively, indicating substantial contributions to the field of HIIT and oxidative stress. Canada, Iran, and Australia have contributed 15, 13, and 12 documents, respectively. Additionally, Denmark, Spain, and Poland have 10, 9, and 8 publications, respectively, demonstrating growing

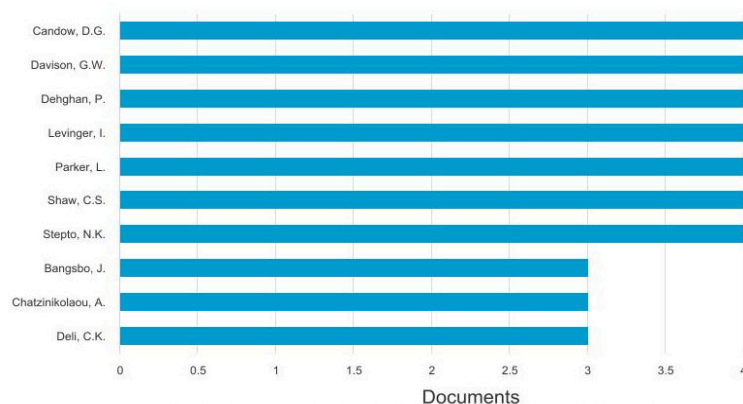


Fig. 7. Top Authors and their publication counts

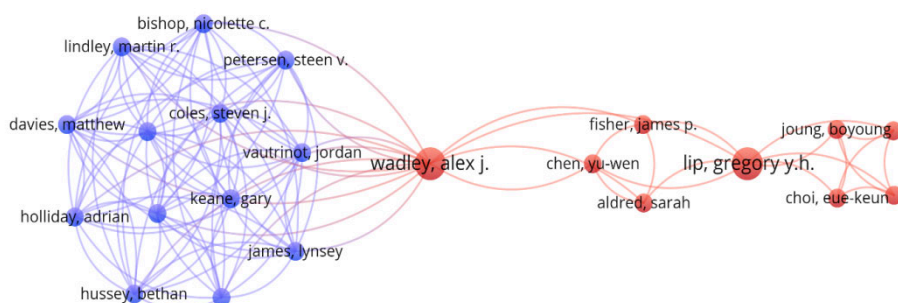


Fig. 8. Co-authorship between authors

RQ1: What is the annual trend in research on oxidative stress and HIIT?

The publication trend for research on HIIT and oxidative stress is illustrated in Figure 2, which provides valuable insights. From 2003 to 2014, the number of publications remained relatively stable, ranging from 1 to 4 per year. From 2014, there was a marked increase, continuing until 2020. In 2021 and 2022, there was a slight decline in the number of publications; however, in 2023, the number of publications surged again, reaching a peak with 35 publications.

RQ2: Which authors have contributed most to research on oxidative stress and HIIT?

Result revealed that Candow, D.G., Davison, G.W., Dehghan, P., Levinger, I., Parker, L., Shaw, C.S., and Stepto, N.K. are the most prominent authors, having published 4 papers each, as shown in figure 7.

RQ3: Which subject areas have published the most research on oxidative stress and HIIT?

Figure 3 illustrates that the field of Medicine has produced the highest number of papers on HIIT and oxidative stress, with 133 publications. Biochemistry ranks

second with 79 publications. Nursing and Health Professions are ranked fourth and fifth, respectively. Other prominent subject areas include Agricultural and Biological Sciences, Chemistry, Pharmacology, Toxicology and Pharmaceutics, and Neuroscience.

RQ4: Which countries are leading in the publication of research on oxidative stress and HIIT?

Figure 6 shows the leading countries in terms of publication output. The United States holds the top position with 26 papers, closely followed by China with 24 publications. Other notable countries include the United Kingdom, Brazil, Canada, and Iran.

RQ5: What are the key terms associated with oxidative stress and HIIT?

In the final network analysis, 3,056 keywords were selected. These keywords were categorized into four clusters: Cluster 1 contains 111 keywords, Cluster 2 contains 108 keywords, Cluster 3 includes 101 keywords, and Cluster 4 consists of 25 keywords. The most frequently used keywords are “oxidative stress,” “high intensity interval training,” and “human,” while less common keywords include “obesity,” “body mass,” “insulin,” and “dietary supplement.”

RQ6: Which publication has the most citations in the field of oxidative stress and HIIT?

Table 3 highlights the most cited publications in the field. Gibala and McGee (2008) are identified as the most influential authors with their study titled “Metabolic Adaptations to Short-Term High-Intensity Interval Training: A Little Pain for a Lot of Gain?” This publication has received 523 citations. Additionally, Ramos et al. (2015) has received 488 citations, while Jelleyman et al. (2015) has been cited 409 times.

Theoretical Implications

The present study makes the following contributions:

This study provides the first bibliometric analysis of HIIT and oxidative stress within the Scopus-indexed literature.

The outcomes of this bibliometric analysis will offer significant benefits to the academic community by guiding future researchers in exploring novel areas of inquiry and establishing a comprehensive foundation for diverse and impactful research projects.

Limitation of the Study

Despite the objective and comprehensive nature of the data analysis in this study, several limitations should be acknowledged. First and foremost, this bibliometric analysis is limited to articles indexed in the Scopus database, excluding other major databases such as Web of Science and PubMed. Second, the analysis is confined to studies published between 2003 and 2024, thereby excluding research conducted prior to 2003. Finally, this study only includes publications in English, omitting research published in other languages.

Conclusion

The study presents a bibliometric analysis of 192 studies on HIIT and Oxidative Stress from 2003 to 2024 based on the scopus database, revealing a significant increase in research activity since 2014, with a peak in 2023. Key contributors include Candow and Davison, with the Medicine field dominating with the highest number of publications. Geographically, the United States and China are the top contributors, followed by the United Kingdom, Brazil, Canada, and Iran. Keyword analysis highlights core terms like “oxidative stress,” “HIIT,” and “human,” while less frequent terms include “obesity” and “dietary supplement.” Gibala and McGee (2008) publication is the most cited, indicating its substantial impact on the field. These findings highlight the growing interest and diverse contributions to HIIT and oxidative stress research.

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Conflicts of Interests

The authors declared no conflicts of interest regarding the study.

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Аналіз дослідницьких тенденцій щодо вивчення високоінтенсивних інтервальних тренувань та оксидативного стресу: Бібліометричний аналіз (2003-2024)

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

Реферат. Стаття: 9 с., 3 табл., 8 рис., 25 джерел.

Історія питання. Оксидативний стрес, індукований фізичними вправами, який часто виникає внаслідок виконання високоінтенсивних інтервальних тренувань (ВІТ), може викликати короткострокове зниження результативності через зміни у функціонуванні клітин та ДНК. Враховуючи цей факт, маркери оксидативного стресу привертають підвищену увагу через їхню потенційну роль у зниженні ризиків та поліпшенні показників індивідуальної результативності.

Мета дослідження. Дослідження мало на меті сприяти дослідникам і практикам у розумінні сучасних наукових тенденцій та вивченні подальших напрямків досліджень у галузі оксидативного стресу та ВІТ.

Матеріали та методи. У статті представлено комплексний бібліометричний огляд та візуалізацію досліджень з вивчення оксидативного стресу під час виконання ВІТ, що включає аналіз 192 публікацій з наукометричної бази даних Scopus. З метою отримання даних було обрано базу даних Scopus з огляду на її авторитетність як бази даних цитування Elsevier, високу якість рецензованих робіт та чотири метрики: h-індекс, CiteScore, SCImago Journal Rank (SJR) та Source Normalized Impact per Paper (SNIP).

Результати. Використовуючи різні інструменти візуалізації для аналізу робіт авторитетних науковців, організацій та ключових слів, у статті визначено провідні публікації та ключові дослідницькі кластери щодо вивчення оксидативного стресу в умовах ВІТ.

Висновки. Шляхом проведення аналізів цитування та коцитування посилань, дослідження висвітлює основні теми наукових робіт та новітні тенденції, пов'язані із оксидативним стресом під час виконання ВІІТ.

Ключові слова: високоінтенсивне інтервальне тренування, оксидативний стрес, фізичні вправи, бібліометрія.

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Review Article

Practicing Surya Namaskar: A Sequence of Yogic Postures for Overall Health and Wellness among Healthy Adults

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Abstract

Background. Yoga, an ancient practice rooted in Indian culture, has gained global recognition for its physical and mental health benefits. Among its practices, Surya Namaskar (SN) stands out as a holistic yogic Sun Salutation exercise combining postures, breathing, and mindfulness, offering physical vitality, mental calmness, and a practical solution to the challenges posed by modern sedentary lifestyles.

Objectives. The objective of the present systematic review was to analyze the effect of SN on overall health and wellness of healthy adults.

Materials and methods. A comprehensive search was conducted in five major databases, namely Scopus, PubMed, PubMed Central, Web of Science, and ScienceDirect, using the terms such as “Surya Namaskar”, “Sun Salutation”, “Surya Namaskar and physical fitness”, “Surya Namaskar for adults”, “Sun Salutation for overall health and wellness”, and “Surya Namaskar and sedentary lifestyle”. The articles published in English between 2011 and 2024 were considered in the current review. The systematic search and reporting adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The Quality Assessment Tool for Quantitative Studies was used to analyze the methodological quality of the included articles.

Results. Based on the inclusion and exclusion criteria, 117 articles were initially retrieved, out of which 11 were finally included, encompassing data from 445 healthy adults from three countries, aged between 18 and 65 years. The duration of the SN intervention varied from four to 24 weeks, with session frequency ranging from three days per week to daily, and a diverse number of cycles. The methodological quality analysis revealed that two articles were of strong, six of moderate, and the remaining three of weak quality.

Conclusions. This systematic review concludes that the practice of the yogic Sun Salutation exercise (SN) is beneficial for improving and maintaining physical fitness, physiological health, and psychological well-being, which determine the overall health and wellness of healthy adults.

Keywords: Sun Salutation, public health, general well-being, yoga, adults.

Introduction

In ancient times, yoga the Indian rooted spiritual culture was refined and developed by Rishis (sages), but now it is spread all over the world in a variety of ways. Over the past few decades, yoga has gained significant popularity across the world due to its potential benefits for physical and mental health. Modern yoga integrates various practices—such as postures (asanas), breath control (pranayama), and meditation—that aim at promoting inner peace, physical vitality, and overall well-being (Bussing et al., 2012; Sengupta,

2012). This holistic approach, accessibility, the ability to be practised in groups or individually, and its ability to fit into even the busiest of schedules have made yoga increasingly popular for people of all ages and offer a simple yet effective means for maintaining overall health (Johnston, 2023; Paramashiva et al., 2024; Telles et al., 2021). Moreover, it is now seen as an alternative medicine in various fields of medical science. Most of the current research has shown that yoga is used as a therapy for various physical ailments before progressing to clinical conditions (Devi et al., 2024; Mondal et al., 2018). In today's fast-paced world, people's lives, work, and moves are changing dramatically over time (Parajuli et al., 2023). Due to huge advancements in technology, the conveniences provided by modern gadgets,

assistive devices, and vehicles, such as ride-hailing services like Ola and Uber, as well as innovations like escalators and lifts, have redefined how individuals approach daily tasks. Similarly, the rise of on-demand services, such as food delivery, has further contributed to the shift towards a more sedentary lifestyle. While these advancements have undoubtedly increased comfort and efficiency, they have also led to decreased physical activity among individuals, especially those in office-based or corporate settings, where long periods of sitting have become the schedule. In response, people are seeking natural ways to maintain their health and wellness (Kumar Singhal, 2023). Physical activity is an essential component of a balanced lifestyle, and while some particular professions—such as factory workers—engage in vigorous physical work, homemakers are involved in different household chores, but a significant portion of the population, particularly those in desk-bound professions, find it challenging to incorporate exercise into their daily routines. Yoga, with its minimal space requirements, flexibility in practice, and focus on both physical and mental well-being, has emerged as a practical solution. In yoga, Surya Namaskar (SN), also known as the sun salutation, is a traditional way to express gratitude to the sun in the morning while executing a sequence of physical postures and controlled breathing techniques that are intended to provide a variety of psychological, spiritual, and bodily advantages (Hipparagi & Gangadhar, 2019; Sinha & Sinha, 2014). SN is relatively new to the Western world but common to East Asian populations who perform it as an alternative to traditional methods of aerobic exercise (Mody, 2011). Facing east, When SN is practiced in the early morning, it helps to release stiffness, refresh the body, revive the mind, and purify subtle energy channels. It is thought that the regular practice of SN enhances the sun-based plexus, which broadens one's creative and intuitive potential. An exact breathing pattern is followed during the SN series of asanas. It provides physical strength, flexibility, and mental well-being while revitalizing every single cell in the body (Bhandage et al., 2024). SN comprises a series of postures that allow the spinal column and the upper and lower limbs to flex and extend through their full range of motion. It requires extended stretches in various body areas and improves flexibility by causing muscle and connective tissue to extend through elastic elongation (Krishma, 2024; Suwannakul et al., 2024). SN combines 12 postures where 7 different asanas are performed in a sequential manner, such as Pranamasan (Prayer pose), Hasta Utthanasan (raised arms pose), Padahastasan (hand to foot pose), Ashwa Sanchalanasan (Equestrian pose), Parvatasana (Mountain pose), Ashtanga Namaskar (Salute with eight parts or points), and Bhujangasan (Cobra pose), and five asanas Parvatasana (Mountain pose), Ashwa Sanchalanasan (Equestrian pose), Padahastasan (hand to foot pose), Hasta Utthanasan (raised arms pose), and Pranamasan (Prayer pose)—are repeated twice (Kumari et al., 2022; Pal et al., 2024; Venkatesh & Vandhana, 2022). SN is a body-mind technique that helps to reduce tension and anxiety while increasing mental calmness (Stec et al., 2023). Slow breathing exercises may reduce the sympathetic nervous system, heart rate, blood pressure (both systolic and diastolic), cortisol, or stress hormone, and the perception of stress (Bandyopadhyay et al., 2023; Pal et al., 2024). Previous research reported

their findings that SN enhances physical relaxation, mental calmness, and stress dispositions such as somatic stress concern and negative emotions in students (Stec et al., 2023). Increased evidence suggests that SN practices may impact different physical and physiological pathways, such as the cardiorespiratory system and musculoskeletal system, which are affected by sedentary lifestyles and are relevant to disease development and progression (Suri et al., 2025; Wirawan, 2018). The current review was done to gather and summarize the updated empirical evidence based on SN's impact on the overall health and wellness of healthy adults.

Materials and Methods

Search Strategy

For the current review, the literature search was initiated in July 2024 and continued through September 2024. Scopus, PubMed, PubMed Central, Web of Science, and ScienceDirect were thoroughly searched electronically to review the related literature. Reference lists from original and review articles were also considered to find out more studies. The search terms were “Surya Namaskar,” “Sun salutation,” “Surya Namaskar and physical fitness,” “Surya Namaskar for adults,” “Sun salutation for overall health and wellness,” and “Surya Namaskar and sedentary lifestyle.” All identified studies were included in Zotero software. At first, the duplicate articles were removed, and then the remaining articles were screened on title, abstract, and full text for eligibility. The systematic search of the present study was conducted according to Preferred Reporting Systematic Reviews (PRISMA) (Page et al., 2021) without meta-analysis and depicted in the PRISMA flow chart (Fig. 1). Also, specific study characteristics and report characteristics of the present study were conducted according to the Preferred Reporting Systematic Reviews (PRISMA2020).

Inclusion Criteria

The relevant studies investigated the effect of Surya Namaskar (SN) on the health and wellness of healthy adults meeting the following criteria were considered for review:

- **Articles:** All the articles have been published in English since 2011 through databases like Scopus, PubMed, PubMed Central, Web of Science, and ScienceDirect, as well as the relevant studies found in the references list.
- **Participants:** The healthy adults of the mean age of 18 years and above.
- **Intervention:** Only SN practice with any frequency and duration was included in the present review.
- **Outcomes:** The investigations that measured any of the physical fitness components such as strength, speed, flexibility, and coordination, any of the physiological variables such as heart rate, blood pressure, body mass index, body fat percentage, waist-hip ratio, sleep quality, cardiorespiratory fitness such as VO_2 max, oxygen consumption, vital capacity, inspiratory capacity, tidal volume, maximum ventilatory volume, peak expiratory flow rate, forced expiratory volume in one second, respiratory exchange ratio and any of the psychological variables such as depression, anxiety, stress, general well-being and cognitive functions like attention and

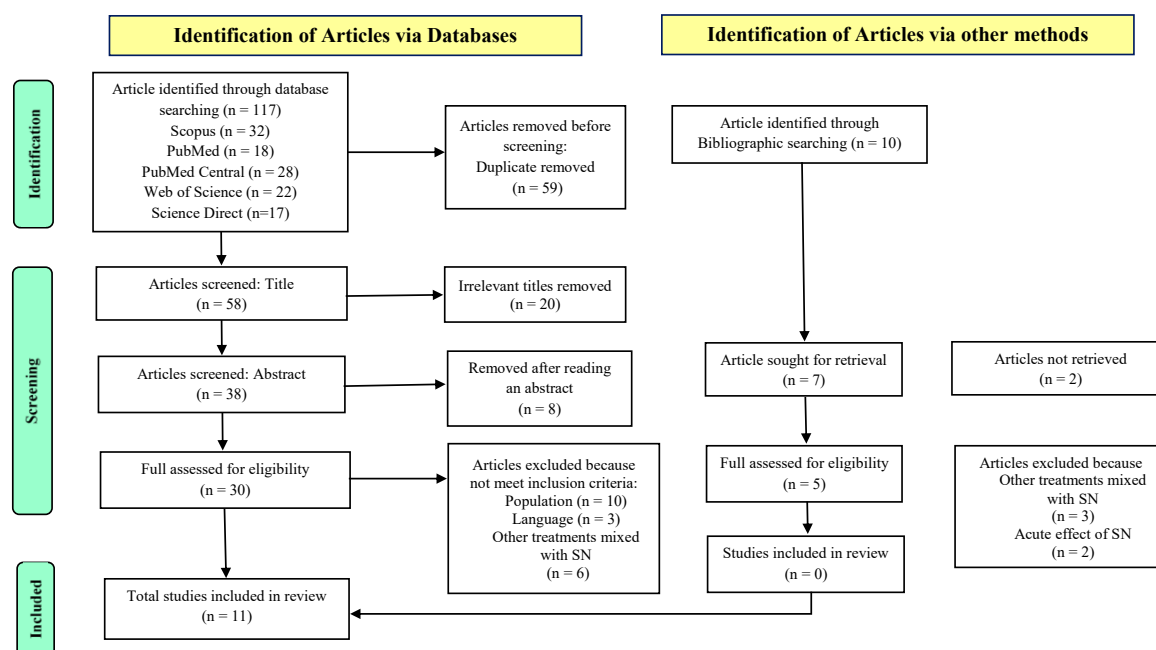


Fig 1. Search process and selection of the study (PRISMA 2020 flow diagram)

orientation, memory, fluency, visuospatial etc. were included.

- Study design: Random controlled trial (RCT), pre-post, repeated measure design, and pilot studies were considered.

Exclusion criteria

Studies were excluded for the following reasons:

- Studies conducted on participants who were suffering from chronic physical illnesses.
- Other yoga interventions like asanas, meditation, etc., combined with SN as a protocol, were excluded from the present review.

Quality assessment and risk of bias

The methodological quality and risk of bias of the included studies were assessed using the Quality Assessment Tool for Quantitative Studies (Thomas et al., 2004) by two researchers (TD and SM) individually. The tool has seven domains: selection bias, study design, confounders, blinding, data collection methods, withdrawals, and dropouts. Each domain was rated as strong, moderate, or weak, which indicates low, moderate, or high risk of bias in the included studies. Discrepancies were resolved through discussion with the remaining researcher (NB).

Results

Study Details

A total number of 117 studies were initially searched through five databases and reference lists: Scopus (32), PubMed (18), PubMed Central (28), Web of Science (22), and Science Direct (17). After the title, abstract, and full

article screening, 30 studies were included for further analysis and assessment for eligibility. Based on inclusion and exclusion criteria, finally, 11 studies were included in the present systematic review. The entire study selection process is presented in Fig 1. All included studies were current and published between July 2011 and July 2024 and were RCT, pre-post, repeated measure designs, and pilot studies.

Participants

A total of 445 healthy adults aged between 18 and 65 years participated from three countries, viz., India, Indonesia, and Thailand. Out of 433 participants, 316 healthy participants underwent SN training, and the remaining 105 participants were part of control groups and other exercise groups. In the present systematic review, out of 11 included studies, only five (Balaji et al., 2024; Chawla et al., 2022; Dubey & Choudhary, 2024; Raja, 2023; Suwannakul et al., 2024) had a control group, while two (Mangaonkar & Puntambekar, 2018; Singh et al., 2017) had another exercise group, and the remaining four (Bhutkar et al., 2011; Karasugi et al., 2023; Kaur, 2021; Kodidala et al., 2021) had no control or other exercise group (Table 1).

Intervention Details

The present systematic review exclusively included experimental studies to observe only the effect of Surya Namaskar (SN) training on the overall health and wellness of healthy adults. SN, the yogic sun salutation exercise consists of 12 postures that are performed in a definite sequence depicted in Fig. 2. The minimum intervention span of SN in the included studies was four weeks, and the maximum duration was 24 weeks. The duration of the SN intervention varied greatly among the studies, ranging from daily intervention over six weeks to six days of intervention

Table 1. Details of study characteristics

Authors, Year, Country	Study details	Intervention details		Study design	Dependent variables	Outcomes
	Sample size Group Age range (R)/ mean age (M)	Intervention Span (IS), Session Frequency (SF), Session Duration (SD), No. of Cycles (C)				
Bhutkar et al., 2011 India	n = 79, EG= Male (49); Female (30), M = above 18 years	IS= 24 weeks, SF= 6 days/week, SD= NM, C= 24		Pre-post test (one group)	Muscle strength (upper and lower body), general body endurance, BMI, body fat (%), LBM	Improvement in muscle strength and general body endurance and LBM for male and female (p < 0.001), decreased body fat (%) for female (p < 0.001).
Singh et al., 2017 India	n= 40, EG1 (SN)= 20; EG2= 20, R= 18-30 years	IS= 6 weeks, SF= daily, SD= 5 minutes, C= NM		Pilot study	Respiratory parameters -TV, IC, VC, FEV1, MVV, PEFR	Improvement in TV, IC, VC, and MVV (p <0.001), PEER (p <0.01), FEV1(p <0.05).
Mangaonkar & Puntambekar, 2018 India	n=30, EG1 (SN)= 15; EG2= 15, R= 19-25 years	IS= 4 weeks, SF= NM, SD= 15 minutes, C= 8		Pre-post test (two group)	Hamstring flexibility	Improvement in flexibility (p=0.05)
Kaur, 2021 India	n= 15, EG= Male (15), R= 18-23 years	IS= 6 weeks, SF= 5 days/week, SD= 30-40 minutes, C= NM		Repeated measure (one group)	Strength, speed, endurance, flexibility and coordination	Improvement in all variables (0.05 level)
Kodidala et al., 2021 India	n= 85, EG= Male (50); Female (35), R= 18-25 years	IS= 12 weeks, SF= 6 days/week, SD= 60 minutes, C= NM		Pre-post test (one group)	Cardiovascular- respiratory parameters (VC, MVV, PEFR, VO2max) and cognitive functions (attention and orientation, memory, fluency, visuospatial)	Decreased pulse rate, BP (systolic and diastolic) (p<0.001), increased VC, MVV, PEFR, VO2max, and all cognitive parameters (p<0.001)
Chawla et al., 2022 India	n= 30, EG= 15; CG= 15, R= 18-40 years	IS= 8 weeks, SF= 3 days/week, SD= 40-45 minutes, C= 3+		Pre-post test (two group)	Sleep quality, GWB, HR, BP	Improvement in sleep quality, RHR and BP (p=0.01), and general well-being (p<0.05)
Karasugi et al., 2023 Indonesia	n= 20, EG= Male (11); Female (9), M= 59.25 ± 6.98 years	IS= 8 weeks, SF= 3 days/week, SD= 50 minutes, C= 3		Pre-post test (one group)	Flexibility of the upper and lower limbs twice	Improved upper and lower limb flexibility (p=0.001)
Raja, 2023 India	n= 30, EG= Male (15); CG= Male (15), R= 50-60 years	IS= 12 weeks, SF= 6 days/week, SD= 2 sessions/day, C= NM		Pre-post test (two group)	Depression and trunk flexibility	Decreased depression (p=0.05) and improved trunk flexibility (p=0.05).
Dubey & Choudhary, 2024 India	n=30, EG= Female (15); CG= Female (15), M= 20.80±0.52 years	IS= 6 weeks, SF= NM, SD= 22-35 minutes, C= 7+		Pre-post test (two group)	Back flexibility and lumbar flexion	Improvement in all selected variables (0.05 level).
Suwannakul et al., 2024 Thailand	n= 44, EG= Female (22); CG= Female (22), R= 19-22 years	IS= 8 weeks, SF= 3 sessions/ week, SD = 50 minutes, C= NM		RCT	Perceived stress, BMI, WHR, body fat percentage, Grip and leg strength, Forward trunk flexibility and VO2max	Decrease in Perceived Stress and BMI (p<0.05), improvement in forward back flexibility, strength (hand grip, leg) and VO2max (p<0.05).

Table 1 (continued)

Balaji et al., 2024 India	n= 30, EG= Male (15), CG= Male (15), R= 18-20 years	IS= 6 weeks, SF= 5 days/week, SD= 45-60 minutes, C= NM	Pre-post test (two group)	Back flexibility and lumbar flexion	Improvement in both back flexibility and lumbar flexion (0.05 level).
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n - sample size; EG – experimental group; NM - not Mentioned; RCT – randomized controlled trial, BMI - body mass index; WHR - waist-hip ratio; TD - tidal volume; VC - vital capacity; IC - inspiratory capacity; MVV - maximum ventilatory volume; GWB - general wellbeing; PEER - peak expiratory flow rate; FEV1 - forced expiratory volume in one second; RER - respiratory exchange ratio; BP - blood pressure; HR - resting heart rate; p - level of significant; VO2max - maximal oxygen uptake

Table 2. Quality assessment and risk of bias of the included studies

Authors	Selection bias	Study design	Confounders	Blinding	Data collection method	Withdrawals and dropout	Overall rating
Bhutkar et al., 2011	M	M	M	W	S	S	M
Singh et al., 2017	S	S	S	W	S	S	M
Mangaonkar & Puntambekar, 2018	W	S	S	W	S	W	W
Kaur, 2021	S	M	M	M	S	S	S
Kodidala et al., 2021	W	M	M	M	S	S	M
Chawla et al., 2022	M	S	W	M	S	S	M
Karasugi et al., 2023	M	M	M	W	S	S	M
Raja, 2023	M	M	S	M	S	W	M
Dubey & Choudhary, 2024	W	S	W	M	S	S	W
Suwannakul et al., 2024	M	S	S	M	S	S	S
Balaji et al., 2024	W	S	W	W	S	S	W

S – strong; M– moderate; W – weak

per week over 24 weeks. Furthermore, for the session, the minimum time was five minutes, and the maximum time was 60 minutes. Information about the length of holding posture was only reported in three studies (Balaji et al., 2024; Dubey & Choudhary, 2024; Mangaonkar & Puntambekar, 2018). Only five of the 11 studies described the cycle of SN intervention in detail (Bhutkar et al., 2011; Chawla et al., 2022; Dubey & Choudhary, 2024; Karasugi et al., 2023; Mangaonkar & Puntambekar, 2018) while the remaining studies did not report the cycle of SN intervention. Among the five studies, the intervention group practiced at least three cycles per session and a maximum of 24 cycles.

Study Outcomes

So, the present review considered the overall health and wellness outcomes confined to three broad domains, i.e., physical fitness, physiological health, and psychological health of healthy adults. The experimental studies that included Surya Namaskar (SN) as independent variable and physical fitness components such as flexibility, strength, speed, coordination; physiological health such as cardiorespiratory fitness (tidal volume, inspiratory capacity, vital capacity,

maximum ventilatory volume, forced expiratory volume in one second, peak expiratory flow rate), body mass index, resting heart rate, blood pressure, maximal oxygen uptake (VO₂max), oxygen consumption, body fat percentage, lean body mass, waist-hip ratio, sleep quality; and psychological health such as perceived stress, depression, general wellbeing; and cognitive functions such as attention and orientation, memory, fluency, and visuospatial as dependent variables have been considered for present systematic review. Based on inclusion and exclusion criteria, 11 studies were analyzed. Out of 11 studies, only eight studies (73 %) considered physical fitness variables such as strength (upper body muscle strength, lower body muscle strength, and grip strength), speed, endurance, flexibility (trunk, back, hamstring, upper and lower limb), coordination, and lumbar flexion, and all studies found significant improvement at the 0.05 level (Balaji et al., 2024; Bhutkar et al., 2011; Dubey & Choudhary, 2024; Karasugi et al., 2023; Kaur, 2021; Mangaonkar & Puntambekar, 2018; Raja, 2023; Suwannakul et al., 2024) while two studies (Bhutkar et al., 2011; Karasugi et al., 2023) found improvement at the 0.001 level. Furthermore, only five studies out of 11 (45 %) considered physiological and cardiorespiratory fitness variables (tidal volume, inspiratory

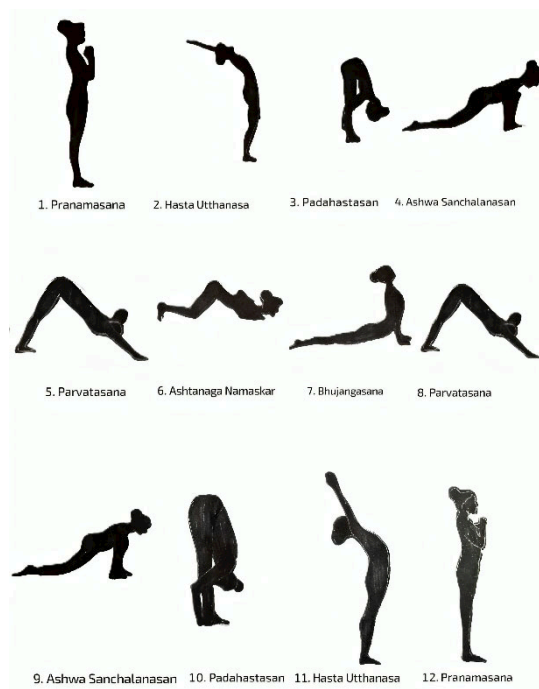


Fig. 2. Surya Namaskar: postures and sequence

capacity, vital capacity, maximum ventilatory volume, forced expiratory volume in one second, peak expiratory flow rate, maximal oxygen uptake, oxygen consumption), body mass index, resting heart rate, blood pressure, body fat percentage, lean body mass, waist-hip ratio, and sleep quality, significant improvement was observed in all parameters among the studies (100 %) (Bhutkar et al., 2011; Chawla et al., 2022; Kodidala et al., 2021; Singh et al., 2017; Suwannakul et al., 2024). In the current review, psychological variables were considered by three studies, and all studies found significant improvement in depression, perceived stress, and general well-being (Chawla et al., 2022; Raja, 2023; Suwannakul et al., 2024). Furthermore, among those, one study (9 %) reported significant improvement (100 %) in cognitive functions such as attention and orientation, memory, fluency, and visuospatial (Kodidala et al., 2021).

Quality Assessment and Risk of Bias

The quality of the included studies was assessed by the Quality Assessment Tool for Quantitative Studies and revealed that two studies were of strong quality, six were of moderate, and the remaining three were of weak quality. The results are depicted in Table 2.

Discussion

The current review aimed to synthesize and analyze updated experimental studies on the impact of Surya Namaskar (SN) on the overall health and wellness of healthy adults. Following an extensive search across five databases, 11 articles were selected for inclusion. All studies employed SN practice as a treatment protocol, with two studies including more than one experimental group (SN). The intervention durations varied widely, ranging from

four weeks to 24 weeks, with frequencies of three to seven sessions per week. The dependent variables were grouped into three domains: physical fitness, physiological health, and psychological well-being.

Physical Fitness Domain

Out of eight studies addressing physical fitness, five specifically examined flexibility as a dependent variable (Balaji et al., 2024; Dubey & Choudhary, 2024; Karasugi et al., 2023; Kaur, 2021; Mangaonkar & Puntambekar, 2018). All five reported significant improvements, attributed to the dynamic flow of 12 asanas in SN that alternately stretch and contract various muscles. Key postures, such as Padahastasana (Hand-to-Foot Pose), Ashwa Sanchalanasana (Equestrian Pose), and Bhujangasana (Cobra Pose), were particularly effective in enhancing flexibility (Geetanjali et al., 2023; Hipparagi & Gangadhar, 2019). SN involves a combination of forward and backward bending postures, which engage and stretch muscles, and joints in the arms, shoulders, legs, and core. This stretching includes flexibility while the weight-bearing aspects (plank position) strengthen the muscles. From a physical health perspective, regular practice of SN enhances blood circulation and muscle functioning in various joints and stimulates various internal organs, which helps to increase muscle endurance and improve the range of motion in joints, reducing the risk of injury (Balaji et al., 2024; Bhutkar et al., 2011; Dubey & Choudhary, 2024).

Three studies investigated the effect of SN on strength, reporting significant improvements in upper-body and core strength due to weight-bearing postures such as Ashtanga Namaskara (Eight-Limbed Pose) and Bhujangasana (Bhutkar et al., 2011; Kaur, 2021; Suwannakul et al., 2024). These asanas involve isometric contractions, engaging muscles such as the pectoralis major, deltoid, biceps brachii, triceps brachii, and rectus abdominis. This suggests that SN offers benefits comparable to resistance training. Additionally, one study reported improvements in speed and coordination after six weeks of practice, although detailed mechanisms were not provided (Kaur, 2021).

Physiological Domain

The dynamic and repetitive nature of SN raises the resting heart rate, and blood pressure leading to cardiorespiratory fitness. By synchronizing the controlled breathing and dynamic movement, practitioners achieve enhanced oxygen uptake (VO_{2max}), improve aerobic capacity and fitness, promote heart health and increase the efficiency of the cardiovascular system (Malhotra et al., 2023). Two out of three studies focused specifically on cardiorespiratory health, noting enhanced aerobic capacity, improved oxygen exchange, and strengthened respiratory muscles (Kodidala et al., 2021; Singh et al., 2017). This is attributed to the deep inhalation and exhalation techniques that increase oxygen exchange in the lungs, strengthening the diaphragm and improving overall respiratory health (Bhutkar et al., 2008; Hipparagi & Gangadhar, 2019). Further, the movement of abdominal muscles during poses like Bhujangasana (Cobra pose) and Uttanasana (Forward bend) stimulates the digestive system (Kumari et al., 2022). SN also regulate endocrine functions. The posture involves stretching and

compressing various glands in the body, such as the thyroid, pituitary, and adrenal glands, which can stabilize hormone levels. This movement also stimulates the nervous system and promotes hormone secretion (Geetanjali et al., 2023; Kumari et al., 2022; Venkatesh & Vandhana, 2022).

SN also positively influences metabolic health, with studies showing improved insulin sensitivity, glucose metabolism, and fat-burning processes (Hipparagi & Gangadhar, 2019; Mody, 2011). Regular practice helps regulate blood sugar levels, reducing the risk of metabolic disorders such as type 2 diabetes. Moreover, several studies highlighted reductions in blood pressure and heart rate, linked to enhanced vagal tone and reduced sympathetic discharge (Chawla et al., 2022; Kodidala et al., 2021). The calming effect of SN's rhythmic breathing further reduces cortisol levels, promoting relaxation and improved cardiovascular health (Pal et al., 2024).

SN's impact extends to sleep quality, with one study reporting significant improvements attributed to reduced cortisol levels and muscle relaxation through sustained practice (Chawla et al., 2022). This highlights SN's potential to alleviate physiological arousal and foster restorative sleep.

Psychological Domain

The meditative and rhythmic nature of SN contributes to enhanced mental health and wellness. Among three studies addressing the psychological domain, significant reductions in perceived stress (Suwannakul et al., 2024) and depression (Raja, 2023) were observed. Research suggests that SN stimulates the parasympathetic nervous system (responsible for relaxation and recovery) while calming the sympathetic nervous system (responsible for stress and the 'fight or flight' response) and promotes mental clarity (Raja, 2023; Stec et al., 2023; Suwannakul et al., 2024). SN stimulates endorphins, often referred to as "feel-good hormones," which elevate mood and create a sense of well-being. This is particularly effective in mild depression and reduces anxiety by lowering the level of cortisol (the stress hormone), enhancing emotional stability, and making it a holistic practice for promoting psychological health (Joshi et al., 2022). Research study shows that regular practice of SN has been shown to improve focus, memory, mindfulness, attention, orientation, fluency, visuospatial, and overall cognitive function by increasing the flow of oxygen-rich blood to the brain (Kodidala et al., 2021). Also, studies have demonstrated that SN can help sharpen mental faculties and decision-making skills (Mody, 2011).

A comprehensive narrative review of research conducted by Netke and Shegokar (2024) highlights numerous health benefits associated with SN, such as improved cardiovascular health, flexibility, stress reduction, and weight loss (Netke & Shegokar, 2024). The review identified that regular practice of SN enhances cognitive functions, reduces cortisol levels, and improves hormone balance, which positively influences both physical and psychological well-being (Netke & Shegokar, 2024). Furthermore, a comprehensive preliminary review of 87 articles revealed that SN has been extensively studied for its physiological, psychological, and health-related benefits, with an increasing number of publications in recent years (Das, 2023). Another review conducted by Venkatesh and Vandhana (2022) accentuates

the importance of SN, highlighting its effect on physical, physiological, and psychological aspects of the body, and proposes that SN practice could be a group activity of the family (Venkatesh & Vandhana, 2022). Also, enlighten the benefits of SN practice has a positive effect on puberty, the menstrual cycle, and childbirth. Overall, the findings of the present systematic review showed that SN provides a comprehensive workout for the body, mind, and spirit, and its combination of breathwork, movement, and mindfulness cultivates physical fitness, enhances physiological processes, manages psychological health and improves cognitive functions, making it a highly effective practice for improving overall health and well-being. Sushika and Ashwitha (2024) found a strong correlation between SN practice and human health that showed sparing a 10-minute per day SN practice can cause a dramatic change in the human life (Sushitha & Ashwitha, 2024).

Study Limitation

This review acknowledges several limitations within the included studies, such as heterogeneity in the age of healthy adults, sample sizes, intervention protocols (especially the total duration, frequency per week, and the number of cycles per session), and follow-up durations. The present review was conducted on the articles that were published in the last 14 years (2011-2024). The studies published in English were only included, and thereby the study might have publication bias. The current review could not include a large number of randomized controlled trials due to their unavailability, and also the quality of the included studies was not strong. Future experimental research should focus on standardizing intervention designs and exploring long-term effects to establish more robust conclusions.

Strength and Practical Implication

The present systematic review considered the studies that were conducted only on healthy adults. The current review was focused on the effect of only the SN intervention. Moreover, the current review included studies that covered a wide range of physical, physiological, and psychological variables that can correctly signify the overall health and wellness status of the adult population. Moreover, this is the first and only systematic review that focused on the impact of a very well-known and well-practiced yogic posture, SN. The critical analysis of the empirical evidence revealed that the sun salutation, a short-duration sequential posture execution, is really worthy for maintaining good flexibility, balance, and postural alignment and provides many more physiological benefits. Further, this postural sequence can be practiced within a very small space in a home setting, which will add additional feasibility for the busy individual.

Conclusion

Based on the availability of experimental studies and within the limitations, it may be concluded that the practice of Surya Namaskar is conducive for overall health and wellness of healthy adults. Further, this yogic Sun salutation is a time-honored practice that integrates physical postures, breathing techniques, and mindfulness, offering a comprehensive

approach to health and wellness. In the modern era, where sedentary lifestyles are prevalent, SN provides an accessible and effective means of improving physical fitness that incorporates flexibility, strength, and coordination while promoting mental calmness that may contribute to lowering the level of anxiety, depression, and perceived stress and improving cognitive functions, thereby enhancing general well-being. Regular practice has been shown to positively impact the cardiorespiratory fitness which includes vital capacity, tidal volume, oxygen consumption, and other lung functions making it a practical alternative to traditional forms of exercise. Further SN has a significant impact on physiological health that considers metabolic health, cardiac health, and sleep quality. Its adaptability for various fitness levels and minimal space requirements make it suitable for busy individuals seeking to maintain overall well-being. As evidence supports its multifaceted benefits, SN stands as a valuable tool for promoting holistic health in healthy adults amidst the challenges of contemporary living.

Conflict of Interest

The authors declare that there is no conflict of interest.

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Практикування Сур'я-намаскара: Послідовність йогічних поз для підтримки загального стану здоров'я та благополуччя серед здорових дорослих осіб

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

Реферат. Стаття: 10 с., 2 табл., 2 рис., 41 джерело

Історія питання. Йога, стародавня практика, що сягає корінням у індійську культуру, здобула світове визнання завдяки своїм перевагам щодо зміцнення фізичного та психічного здоров'я. Серед практик йоги варто відзначити методику Сур'я-намаскара (СН) — комплекс йогічних вправ «Вітання Сонцю», що представляє собою комбінацію визначених положень тіла, дихання та розвиток усвідомленості, сприяючи фізичній життєздатності, душевному спокою та практичному вирішенню проблем, пов'язаних із сучасним малорухливим способом життя.

Мета дослідження. Метою цього систематичного огляду було проаналізувати вплив СН на загальний стан здоров'я та благополуччя здорового дорослого населення.

Матеріали та методи. Проведено комплексний пошук у п'яти основних наукометричних базах даних, а саме: Scopus, PubMed, PubMed Central, Web of Science та ScienceDirect, використовуючи терміни, як-от «Сур'я-намаскара», «Вітання Сонцю», «Сур'я-намаскара і фізична підготовленість», «Сур'я-намаскара для дорослих осіб», «Вітання Сонцю для підтримки загального стану здоров'я та благополуччя», а також «Сур'я-намаскара і гіподинамія». У рамках цього наукового огляду розглядалися статті, опубліковані англійською мовою в період з 2011 по 2024 рік. Систематичний пошук і звітування проводились згідно з рекомендаціями «Переважні елементи звітування для систематичних оглядів та метааналізів» (PRISMA). Для аналізу методологічної якості включених статей використовувався інструмент оцінки якості кількісних досліджень (Quality Assessment Tool for Quantitative Studies).

Результати. На основі критеріїв включення та виключення на початковому етапі було відібрано 117 статей, з яких остаточно було включено 11 наукових публікацій, що стосувалися даних щодо 445 здорових дорослих осіб з трьох країн віком від 18 до 65 років. Тривалість інтервенції із застосуванням комплексу вправ СН варіювалася від 4 до 24 тижнів, з частотою сеансів від 3 днів на тиждень до щоденних занять, а також з різною кількістю циклів. Аналіз методологічної якості показав, що дві статті мали високий рівень якості, шість — помірний, а решта три — низький.

Висновки. У цьому систематичному огляді обґрунтовано висновок, що застосування практики, яка передбачає виконання комплексу йогічних вправ «Вітання Сонцю» (Сур'я-намаскара) позитивно впливає на покращення та підтримання фізичної підготовленості, фізіологічного здоров'я та психологічного благополуччя, які визначають загальний стан здоров'я та благополуччя здорового дорослого населення.

Ключові слова: Вітання Сонцю, громадське здоров'я, загальне самопочуття, йога, доросле населення.

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Review Article

The Role of Virtual Reality in Optimizing Karate Performance: Scoping Review

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Abstract

Objectives. The objective of this study was to undertake a scoping review on the role of virtual reality (VR) in optimizing karate performance. The questions to be researched were: (1) how did VR support the training process, (2) what were the challenges of integrating VR, (3) how effective was VR in maximizing performance, and (4) what was the potential of VR in the development of karate training methods.

Materials and methods. The scoping review was employed as a research method. The stages of research included (1) determining the title, (2) determining the study question, and (3) searching for the Scholar, Wiley, Scopus, and Springer database articles with the keywords used comprising Boolean “karate” and “virtual reality” or “VR”. This article search yielded data from Google Scholar 77, Wiley 27, Scopus 52, and Springer 47. (4) The initial screening yielded 150 articles. (5) The second screening yielded 25 articles, and (6) the final data was determined, yielding 9 articles in all. The data collection and analysis techniques included Publish or Perish, Mendeley, and narrative interpretation.

Results. (1) VR is one of the successful applications to enhance karate training, providing a safe and adaptable approach. However, improvements to VR require further research to increase realism, content variation, clear instructions, and long-term testing to be more effective. (3) Combining conventional training and VR has emerged as the most effective method for enhancing karate performance. (4) While VR has positive potential, it is essential to refine the guidelines and standards of use before it can be extensively adopted.

Conclusions. The findings indicate that VR becomes a complementing and efficient training application for improving karate performance.

Keywords: virtual reality, performance optimization, sports technology, karate, scoping review.

Introduction

Virtual reality (VR) is no longer limited to education (Mannir & Getso, 2023). However, it is becoming more widely known and has evolved in the world of sports, particularly karate. VR is a breakthrough that will provide

a new experience for training applications for beginners, intermediate, and professional athletes. Karate needs fast, strong, and precise motions, therefore the presence of VR aids in smooth training. Optimal karate performance demands a combination of striking and kicking techniques, strategy, tactics, and adequate physical condition (Hadi & Yudhistira, 2023; Yudhistira, 2023).

Karate is a physical contact sport (Yudhistira, Siswantoyo, et al., 2021; Yudhistira, Suherman, et al., 2021). There is a greater chance of injury in traditional training while approaching a match. The author's idealism demonstrates

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that VR is a solution for bridging this visualization with real-world situations to enhance fighting skills while retaining the core of the sport of karate. According to another study, one of the barriers to achieving athlete potential in traditional karate training is a lack of sparring partners with various styles and variations, the risk of injury, and the need for structured training conditions (K Petri, Emmermacher, Masik, et al., 2019). These are the fundamental components for the creation of VR for the sport of karate among academics, particularly those from outside. At this point, virtual reality, particularly in the sport of karate in Indonesia, has not received special attention to be revealed in depth; this is the cause why the author performed this review to investigate the challenges and gaps in past research to discover meaning as a foundation for future study.

VR has evolved as an innovative approach to these difficulties by providing each athlete with a consistent, safe, and adaptable real-world environment (Witte et al., 2022). VR is a computer-based simulation technology that creates immersive three-dimensional settings in which sportsmen can interact with circumstances similar to real-world contests. VR is a tool for improving cognitive and motor skills, providing simulation strategies, visual feedback, and endless repetition in a safe environment (Ritter et al., 2022). Previous research has revealed that VR can increase response speed, movement accuracy, and attack recognition of patterns in karate, making it a suitable training tool for improving performance in real competitions (Ghazi et al., 2025).

However, despite its enormous potential, the use of VR in karate instruction confronts certain urgent problems that require immediate attention. First, there is inconsistency in transferring VR training to real-world performance, particularly in terms of physical engagement, adaptation to dynamic match conditions, and decision-making (Stefan Pastel et al., 2021; K Petri et al., 2018; Ritter et al., 2022). Second, there are still no standard criteria for implementing this technology, resulting in variability in training effectiveness and severely limiting innovation for coaches and players. Third, although VR gives extensive options, excessive training without genuine help from coaches might result in technical faults or dependence on the virtual world, potentially damaging to athletes in the long term (Witte et al., 2022).

Furthermore, financing for VR software and gear remains quite pricey, making it difficult for many clubs and athletes to gain access to this technology. In this situation, it poses challenges to the global implementation of VR technology, particularly in developing countries. As a result, it is critical to perform a scoping review study to assess the extent to which VR has been developed and implemented in the context of karate training.

A scoping review is a tool for mapping and exploring prior research by finding gaps, trends, and opportunities in the literature (Munn et al., 2018). Then use the total knowledge to generate future research. Given the availability of VR research in other sports, this approach is critical for integrating these findings into the context of karate, which has unique requirements such as reaction speed, movement pattern recognition, technique mastery, and field mastery that can be fulfilled in the actual world. Given the importance of ongoing VR development, this scoping assessment provides an excellent basis for future research.

Thus, the objective of this research is to conduct a scoping review of the role of VR in improving karate performance. The analysis of the most recent outcomes utilizing precise procedures and phases is expected to provide in-depth insight into the prospects, effectiveness, and challenges of using VR to improve karate performance. Based on the description above, the author proposes research questions such as (1) how VR technology can support the karate training process in improving performance, (2) what are the challenges faced in implementing VR to optimize karate performance, (3) how effective is the implementation of VR compared to conventional training in supporting karate performance, and (4) what is the future potential of VR for the development of karate training methods. This study is likely intended to assist academics, particularly those involved in the sport of karate, in better tracking the development of virtual reality.

Materials and Methods

Study Design

The type of research is a scoping literature review. This is similar to a systematic review, but the distinction is that it asks larger research questions to investigate existing information (Munn et al., 2018). Scoping literature review attempts to study the notion of literature methodically, using a rigid approach, to obtain synthesis and relevant information for future research (Munn et al., 2018).

Eligibility Criteria

The inclusion criteria in this study are as follows: (1) original articles and relevant literature reviews, proceedings from 2019-2025, (2) full text available for download, (3) Written in English, and (4) from Google Scholar, Wiley, Scopus, or Springer. Exclusion criteria include (1) not being published between 2019 and 2025, (3) Not written in English, (4) not being included in the Scopus, Google Scholar, Wiley, or Springer databases, and (5) incomplete text.

Procedures

This research is conducted using a systematic procedure, which is as follows:

- Conduct an observational study and analyze documents in the form of articles to define the research's theme, topic, title, and urgency.
- Determining research questions to focus the discussion so as not to broaden.
- Searching for related publications in the Google Scholar, Wiley, Scopus, and Springer databases using the Boolean keywords "karate" and "virtual reality" or "VR". This approach yielded 77 articles from a Google Scholar search, 27 from Wiley, 52 from Scopus, and 47 from Springer.
- The discovered data is evaluated to find duplicate articles and the relevancy of the articles to a total of 150.
- The articles are filtered again, yielding 25 articles.
- The next stage is to filter for articles that can be downloaded in full, which yields 9 articles.
- Following the team's agreement, the final analysis was conducted, and 9 articles were determined to be eligible.

To clarify, the Preferred Reporting Items for Systematic Reviews (PRISMA) analysis is shown below:

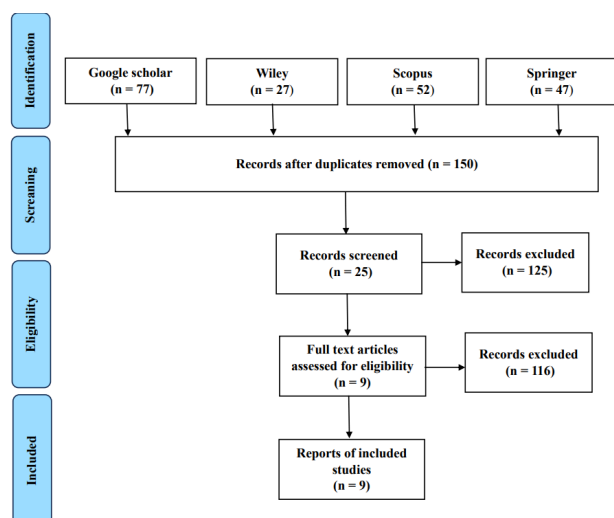


Fig. 1. PRISMA Flowchart of the Research Process

Data analysis

The published or published applications, Mendeley, Google Scholar database, Wiley, Scopus, and Springer all help with data collection and filtering techniques (Hafidz et al., 2024). Data analysis techniques are carried out by

extracting meaning to understand how technology affects karate performance (Yudhistira et al., 2023). It was followed by compiling a narrative that can describe the results of the data information.

Results

Description of the review results based on selected articles through PRISMA analysis.

According to the results of the review analysis, 9 articles were identified as final data. The results of the analysis as a whole explain the development of virtual reality applications as applications to improve performance in terms of physical, technical, and motor skills in beginner, intermediate, and professional karateka, from the results of the 9 articles using experimental, non-experimental methods, concept development, and literature review (Ghazi et al., 2025; Lygouras & Tsinakos, 2024; S Pastel et al., 2023; K Petri, Bandow, & Masik, 2019; K Petri, Emmermacher, Danneberg, et al., 2019; K Petri, Timmerevers, Luxemburg, et al., 2019; Katharina Petri, Masik, Danneberg, et al., 2019; Ritter et al., 2022; Witte et al., 2022).

Discussion

RQ1: How can VR technology support the karate training process in improving performance?

The first argument is that VR is being used to improve the ability to respond quickly and anticipate punches and kicks. Karateka can improve anticipation by detecting attack patterns from the start of an action. According to Petri et al.,

Table 1. Summary of results from the review analysis of 9 documents

No	Author	Objective	Method	Population	Findings	Conclusion
1	(K Petri, Timmerevers, Luxemburg, et al., 2019)	Understanding the potential of VR applications as a learning tool for movement in karate	Experiments with pilot study design	Young karate athletes consisting of 7 women and 11 men	A significant increase was found in the execution of movements in the virtual reality group, and the video group, but not in the control group.	VR applications are ideal for both observational learning and improving physical ability.
2	(K Petri, Emmermacher, Danneberg, et al., 2019)	Understanding whether VR-based training can enhance reaction actions in techniques.	Experiment	15 experienced young karate athletes	Significant effects were found in terms of response time and quality of the VR group.	It was concluded that training with VR was beneficial for improving response actions in young karate athletes.
3	(Katharina Petri, Masik, Danneberg, et al., 2019)	Determining the effect of ten sessions of VR training on response actions and decision-making.	Experiment	15 experienced young karate athletes	The Friedman test results revealed that VR training greatly boosted karate-specific response behavior (as measured by motion analysis). The control group exhibited an increase with a small effect.	Training with VR is effective in enhancing sport-specific responses for young karate athletes.
4	(K Petri, Bandow, & Masik, 2019)	Understanding the impact of VR training on managing virtual opponent attacks	Experiment	15 experienced young karate athletes	Significant effects were found for time and time x group interactions for gyaku-zuki and kizami-zuki and found a time x reaction time effect in gyaku-zuki, but no significant time x reaction time effect for either attack. Paired t-tests showed significant effects for both pretest and posttest results.	These findings can be used to enhance motor learning in beginners to improve performance.

Table 1 (continued)

5	(Ritter et al., 2022)	Understanding the difference in response time and response type between real-time and virtual reality conditions	Non-Experiment	Experienced karate athletes consist of 17 men and 10 women	The results showed that there was no significant difference in response time and response type in virtual reality and the real world. Only the response quality was rated better in the real world.	It was concluded that the response time and response type for kumite category karate athletes in virtual reality conditions were similar to real-world conditions.
6	(Witte et al., 2022)	Understanding the difference between VR and the world in karate training	Experiment	17 male and 10 female karate athletes with international and national competitive levels	The findings revealed that the VR group had a longer response time to the gyakutzuki and kizamitzuki strokes. However, the response quality parameters for both groups did not improve. Athletes provided excellent feedback on the incorporation of VR training into conventional training.	It was determined that karate athletes who underwent VR training had better response times. The assumption that VR training can be applied in real-world scenarios cannot be demonstrated. There is evidence that VR training is effective for intermediate athletes. In the future, VR training tools should include freely engaging opponents.
7	(S Pastel et al., 2023)	Find out how VR compares to video training on the soto uke method that advances with the Zenkutsu Dachii posture.	Experiment	Male and female karate athletes totaling 83.	Results showed that VR was as effective as video training, and the transfer of VR-adapted skills in natural environments was equally adequate.	It is found that VR is an appropriate application for beginning athletes. The benefits of VR have yet to be completely shown, which is why the performance results are similar to those of other groups. As a result, further study is required to advance virtual reality.
8	(Lygouras & Tsinakos, 2024)	The goal of VR is to create a realistic training environment, evaluate performance, and enhance the development of technical skills.	Scoping review	Synthesis of the article consists of 7 documents.	Immersive technology, especially VR, offers the ability to record and capture precise movements that provide detailed feedback on reaction time, technique, and decision-making. This requires athletes and coaches to identify areas for improvement and adjust training based on the data.	It is concluded that, while immersive technology has a good influence, there are currently no clear frameworks or rules for its proper deployment in karate training. Thus, best practices and guidelines are required to enable optimal integration.
9	(Ghazi et al., 2025)	Exploring VR and AI applications to enhance karate performance	Descriptive exploratory	Concept development with several relevant articles	The primary papers discovered were (1) producing a meaningful and intuitive body movement-based self-image presentation to optimize practice, and (2) developing an efficient and professional model.	The application of VR and AI in karate training greatly enhances technique precision, movement efficiency, motivation, and feedback, resulting in fewer injuries. More research is expected to improve the technology's accuracy and efficiency, integrate virtual and real-world training, and ensure player safety.

installing the VR application can determine the response in the early stages of an attack by assessing the opponent's reach and steps to strike (K Petri, Bandow, & Masik, 2019). VR has been widely regarded as a tool to aid athlete training. The technology simulates a real-world environment to improve response time and anticipation in a variety of match situations. This enables athletes to respond to visual

and aural cues similar to those encountered in real-world circumstances. Other studies suggest that VR improves physical performance, concentration, and motivation; therefore, VR is frequently used in endurance sports such as running, rowing, and cycling (Neumann et al., 2017). Simulations in virtual environments can provide a degree of focus and feedback that influences (Neumann et al., 2017).

The second topic is about VR being a safe practice for karate athletes. VR implementation for athletes can practice simulation methods without the risk of injuries caused by physical touch (Ritter et al., 2022). Simulation in VR allows athletes to repeat moves without any physical impact, which allows them to enhance their talents safely. A diversified approach to match simulation enables the discovery of many sorts and fighting techniques, boosting each individual's adaptability and strategy. Furthermore, athletes can simulate various scenarios and prepare for problems that may arise in real competition (Witte et al., 2022). The VR technique may be used anywhere and at any time, allowing athletes to train on their schedule (Lygouras & Tsinakos, 2024). Technology advances, providing increasingly realistic and interactive experiences that promote athlete participation in training.

As a result, the usage of virtual reality has proven to be an effective exercise for improving reaction speed, response, and anticipation. Furthermore, it is a safe and adaptable strategy for athletes. As a coach, this technique provides a tool and exposure to new ways of optimizing training programs. Virtual reality allows athletes to learn important skills safely and effectively. As a result, the first research question can be answered: VR can be a significant component in sports training programs, particularly in the sport of karate.

RQ2: What are the challenges faced in implementing VR to optimize karate performance?

As a result, there are benefits and drawbacks to using virtual reality to help in training. Discussing the disadvantages, notably that karate martial arts require physical contact, particularly in the fighting category, so that training remains relevant when training in real-time, degrading the nature of karate itself. However, when addressing the benefits, it is important to note that in the present era, training models and infrastructure require a touch of technology to make training more efficient and successful using a VR approach. Similarly, sportsmen can use VR for simulation training that involves elements of strategy, reaction speed, and improvisation. In this situation, how might coaches use VR as an addition to real-time training, rather than a replacement, to help training and matches operate smoothly?

The first point is that, while VR is excellent for training techniques and tactics, it cannot completely replace conventional training. For example, strength training involving external loads is not available in VR, so training with VR cannot completely replace conventional training. Another physical constraint is that VR can not mimic normally built physical training, such as stamina and agility, which cannot be fully performed with VR.

The second point addresses costs and infrastructure. Although VR technology is becoming more inexpensive, deployment still requires a significant initial investment. Furthermore, certain dojos and athletes may not have access to hardware like VR headsets and sensors. Next, consider the limitations of direct technical training. That martial arts place a premium on precise movement and physical contact. Although VR gives excellent imagery modeling, tactical features such as touch when hitting a target are impossible to recreate using present technology. Furthermore, the level of authenticity in some VR training can limit direct experience,

which is critical in outsmarting and reading opponents when close range, long range, and timing are all important in karate.

According to a study by Petri et al., several challenges indicate that the implementation of VR requires further development, including increased realism, content variation, and long-term testing, for VR to be an effective application (K Petri, Timmerevers, Luxemburg, et al., 2019). Other studies say that technical, methodological, and implementation obstacles must be overcome before VR may become a more integrated tool (K Petri, Emmermacher, Danneberg, et al., 2019). VR solely provides visual inputs and no additional sensory stimulation, such as sound or touch. This decreases the immersive experience and the relevance of training to real-world situations (K Petri, Masik, Danneberg, et al., 2019).

Numerous hurdles must be overcome for VR to be a useful tool in the sport of karate. However, future development must focus on precise approaches to achieve effective VR results, such as selecting material specialists who are competent professionals in their disciplines, such as technological experts, professional trainers, and karate scholars. This challenge has piqued the author's interest in further developing VR.

RQ3: How effective is VR implementation compared to conventional training in supporting karate performance?

Discussing effectiveness necessitates extensive testing. The essence of karate is a physical contact sport (Yudhistira, Siswantoyo, et al., 2021). As a result, each exercise undoubtedly includes real movement. However, VR is used as a complement in the sport of karate. VR outperforms video and control groups in terms of observational and motor learning (K Petri, Bandow, & Masik, 2019). This is related to the karate learning approach, whereas other research shows that VR training can help young karate athletes improve their fast response (K Petri, Emmermacher, Danneberg, et al., 2019). Interestingly, not only connected to physical, studies show that the use of training with VR delivers a motivating training experience, resulting in new and safe learning (K Petri, Masik, Danneberg, et al., 2019). Furthermore, another study found that the response time and type of response for karate athletes were equally good in VR and the real world (Ritter et al., 2022), which is consistent with other studies that found that VR was better than the control group for response time, but neither increased for response quality parameters (Witte et al., 2022). Furthermore, athletes reacted strongly to incorporating VR training into traditional training (K Petri, Masik, Danneberg, et al., 2019; Witte et al., 2022). Furthermore, VR training proved as effective as video training for skill development (S Pastel et al., 2023).

As a result, the use of VR in conjunction with real-world training benefits karate athletes. However, the testing was only partial in terms of response time and motor motions. Other factors, such as agility versus reactive, have not been evaluated. The sport of karate, particularly kumite, requires a high level of reactive agility (Yudhistira & Tomoliyus, 2020). Then, during VR testing, it focuses just on punching. Meanwhile, extremities like kicks have received little attention when it comes to VR applications. Karate athletes rely heavily on their legs. For example, as an athlete moves forward to approach an opponent and backward to avoid an opponent, the power of the leg muscles, as well as the speed and agility to move while kicking, are critical (Yudhistira, 2023).

Furthermore, while VR may be superior in certain ways, more complete testing is required, such as increasing the sample size, using a more complex technique, and controlling for gender and training level. Another study found that, while VR promises unique and established technology and frameworks, there is none for effective use in karate training (Lygouras & Tsinakos, 2024). In this instance, best practices and recommendations are required for optimal integration (Lygouras & Tsinakos, 2024). However, combining traditional training with the use of VR is the most effective way to improve karate performance.

RQ4: What is the potential of VR for the development of karate training methods in the future?

Virtual reality has huge potential to transform karate training methods and sports programming by stressing an engaging, safe, and efficient approach. According to Ghazali et al.'s study, further development research is needed to improve VR, namely in terms of accuracy and usefulness in karate instruction (Ghazi et al., 2024). Furthermore, enhancing the analysis of user movements allows for real-time feedback to guarantee the technique is correct (Ghazi et al., 2024). VR can grasp how to optimize and improve movement efficiency (Ghazi et al., 2024). Immersive VR can make training more enjoyable, leading to greater motivation (Ghazi et al., 2024).

This technology allows athletes to analyze and adjust training tactics, increase response time, and transfer abilities to karate in real-time (Lygouras & Tsinakos, 2024). High interest and motivation in VR training are indicators that it has great potential (S Pastel et al., 2023). The integration of cutting-edge technology enables coaches to track athletes' progress in real-time and provide immediate feedback. VR is more than just an application; it opens up possibilities for actual accessibility. Furthermore, technology can be used to help coaches and athletes perform better (K Petri, Emmermacher, Danneberg, et al., 2019). In this example, VR enables the creation of artificial but realistic circumstances to enhance and evaluate sports performance, making standards and manipulation impossible in reality (K Petri, Timmermans, Luxemburg, et al., 2019).

In response, virtual reality has the potential to positively impact the development of better training methods. VR allows coaches to apply and develop experience in the field of technology, while players can obtain unique training experiences. The future potential of VR requires better regulation of guidelines. It is critical to set standards for the use of VR in karate instruction so that it may be broadly used. So far, existing VR criteria do not include specifications for athletes in the novice, cadet, junior, or senior categories. Then, VR has so far been shown to improve motor abilities and response speed. The rest is such as VR, whose use is now insufficient for physical training programs, technical training, and so on. As a result, additional work is required to provide a higher potential for the development of VR-based training models in the kata and kumite categories that are tailored to the level of training, technological requirements, and so on. If these advancements are implemented, VR in the future will be more engaging and pleasant. The opportunity to have a more in-depth and effective training experience will grow.

Conclusions

Based on the findings and discussions, it is determined that (1) VR is one of the effective applications to enhance ka-

rate training by providing a safe and flexible approach, (2) the challenges in improving VR are that it requires further development in increasing realism, content variation, creating clear guidelines and long-term testing so that VR becomes an effective application, (3) wisely combining conventional training with VR implementation is the best solution to improve karate performance, (4) VR has positive potential to develop better training methods. VR has to strengthen its guiding principles and usage standards so that it may be broadly adopted. Overall, VR is a complementing and useful training tool for improving karate performance, particularly for experienced athletes who need to perfect reflex actions and build strategies in simulations that can be implemented in real matches.

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Conflict of Interest

All authors declare no conflict of interest.

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Роль віртуальної реальності щодо оптимізації результативності у карате: 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: 8 с., 1 табл., 1 рис., 23 джерела

Мета дослідження. Мета цього дослідження полягала в проведенні огляду предметного поля щодо ролі віртуальної реальності (ВР) в оптимізації результативності у карате. Питання, що підлягали дослідженню, були такими: (1) як ВР

сприяла тренувальному процесу, (2) які труднощі виникали у процесі інтеграції ВР, (3) наскільки ефективною виявилася ВР з точки зору максимізації результативності, а також (4) з'ясування потенціалу ВР у розробці методів тренування з карате.

Матеріали та методи. В якості методу дослідження застосовано огляд предметного поля. Етапи дослідження передбачали: (1) визначення назви, (2) визначення питання дослідження та (3) пошук статей у наукометричних базах даних Scholar, Wiley, Scopus та Springer із використанням ключових слів, що містять логічний тип даних «карате» та «віртуальна реальність» або «ВР». У результаті пошуку публікацій було отримано матеріали із наукометричних баз даних Google Scholar 77, Wiley 27, Scopus 52 і Springer 47. (4) Під час первинного відбору отримано 150 статей. (5) У підсумку повторного відбору отримано 25 статей, і (6) визначено остаточні дані, що дозволило отримати загалом 9 статей. Для збору та аналізу даних використовувалися такі методики, як Publish or Perish, Mendeley та нарративна інтерпретація.

Результати. (1) Віртуальна реальність є однією з успішніших програм, що дозволяє покращити процес тренувань з карате, забезпечуючи безпечний та адаптований підхід. Однак, для досягнення більшої ефективності, вдосконалення ВР потребує подальших досліджень з метою підвищення реалістичності, варіативності контенту, чітких інструкцій та довготривалого тестування. (3) Поєднання традиційних тренувань і ВР виявилось найефективнішим методом підвищення результативності у карате. (4) Незважаючи на позитивний потенціал ВР, необхідно вдосконалити інструкції та стандарти використання, перш ніж впроваджувати зазначену технологію у широких масштабах.

Висновки. Отримані дані свідчать про те, що віртуальна реальність стає доповнюючою та ефективною програмою для проведення тренувань у контексті поліпшення показників результативності у карате.

Ключові слова: віртуальна реальність, оптимізація результативності, спортивна технологія, карате, огляд предметного поля.

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Review Article

Technological Innovation in Pencak Silat Training as a Component of Indonesian Cultural Heritage: A Systematic Literature Review

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Abstract

Background. Examining technology integration in Pencak Silat training is considered as an essential aspect, focusing on its potential to enhance physical, technical, and mental performance while preserving its cultural and philosophical values.

Objectives. The study aimed to evaluate the effectiveness of augmented reality (AR), virtual reality (VR), and sensor-based systems in improving skill acquisition, performance monitoring, and training customization. It also addresses challenges in technology implementation and examines its adaptability to practitioners of varying skill levels.

Materials and methods. A systematic literature review (SLR) was conducted in accordance with the PRISMA guidelines. Scopus served as the primary database, focusing on studies published within the past decade. Inclusion criteria prioritized studies addressing technological innovations in Pencak Silat training, while irrelevant or low-quality studies were excluded. Data were extracted using a standardized form and analyzed thematically to identify trends, challenges, and gaps.

Results. The findings highlight significant AR, VR, and sensor technological advancements, demonstrating their effectiveness in enhancing physical and technical performance. However, barriers such as high costs, limited accessibility, and the need for tailored solutions continue to persist. Technology showed varying effectiveness based on athlete competence, with professionals benefiting more from advanced features, while tailored tools proved effective for amateurs.

Conclusions. Technology has revolutionized Pencak Silat training, but its integration requires addressing accessibility and adaptation challenges. Future innovations should combine traditional practices with modern advancements to preserve cultural values.

Keywords: Pencak Silat, augmented reality, virtual reality, sensor technology, training innovation, systematic literature review.

Introduction

Pencak Silat is a martial art deeply rooted in Indonesia and Southeast Asia's cultural and philosophical traditions. Its rich history and unique techniques have solidified its status as a significant component of Indonesia's cultural identity. Over the years, Pencak Silat has evolved from a traditional practice into a globally recognized sport. This

transformation is supported by national and international initiatives, such as its integration into school extracurricular programs in Indonesia, which have significantly increased youth participation (Burhanuddin et al., 2023; Hariono et al., 2024; Sudiana et al., 2023). The Indonesian government has played a pivotal role in promoting Pencak Silat by hosting national and international competitions, further strengthening its position as a competitive sport (Kusuma & Novita, 2023).

Globally, Pencak Silat's inclusion in prestigious events like the Asian Games has elevated its status as a sport of international repute (Irianto & Lumintuarso, 2020; Subekti

et al., 2020). Beyond competition, Pencak Silat's training philosophy combines physical conditioning, mental discipline, and spiritual development. This holistic approach has drawn global attention, fostering cross-cultural collaborations and exchanges (Imtihansyah et al., 2024; Nugroho et al., 2024). Training in Pencak Silat traditionally involves repetitive practice of foundational movements and techniques guided by experienced mentors. This method develops muscle memory and coordination and instills cultural values and discipline (Ihsan, 2021; Karo-Karo, 2023). These elements reflect Pencak Silat's dual role as a physical practice and a medium for cultural preservation making it a vital and dynamic tradition in Indonesia and beyond.

Technological advancements have significantly influenced sports training in the past decade, including traditional martial arts like Pencak Silat. These innovations have modernized training methodologies, making them more interactive and practical. Digital tools and multimedia applications, such as video-based tutorials and simulation software, are increasingly integrated into Pencak Silat training to enhance skill acquisition and performance. Technologies like augmented reality (AR) and virtual reality (VR) provide immersive training environments, enabling athletes to visualize and practice techniques more effectively (Mulyana, 2024; Sampurna et al., 2021a). Wearable devices and sensor-based tools have also emerged as pivotal innovations, offering real-time feedback on performance metrics such as speed, power, and movement accuracy (Ihsan et al., 2024; Maghribi, 2024). These technologies enable athletes and coaches to analyze data and refine techniques more precisely. This shift towards technology-supported training demonstrates the potential of digital innovations to revolutionize the practice of Pencak Silat while preserving its traditional essence.

Despite the transformative potential of technology in Pencak Silat training, several critical gaps remain unaddressed. One prominent issue is the limited research on the long-term impact of technology on skill retention, mental development, and the philosophical core of Pencak Silat. Current studies primarily focus on improving physical performance metrics, such as speed and strength, leaving the integration of mental and spiritual dimensions underexplored (Ihsan et al., 2022; Lanos et al., 2023a; Lubis et al., 2021, 2024). Another gap lies in the accessibility and adaptability of technological tools. Many innovations are not tailored to the unique requirements of Pencak Silat training, which involves complex, dynamic movements. This lack of customization can hinder their effectiveness, particularly for advanced practitioners (Widiastuti et al., 2022). Additionally, logistical barriers, such as the high cost of equipment and limited access to underdeveloped regions, restrict the widespread adoption of these technologies. Addressing these gaps is essential for ensuring inclusive and comprehensive advancements in Pencak Silat training.

The main strength of this study lies in the systematic approach used to summarize and evaluate the current literature on technology integration in Pencak Silat training over the past ten years. Based on the initial analysis, most of the existing studies still focus on the application of technology to improve physical and technical performance, such as kick speed, movement coordination, and explosive

power (Ihsan et al., 2022; Mardius et al., 2024; Wijaya et al., 2024). However, there are still significant research gaps, especially regarding the long-term impact of technology on skill retention, mental development, and the core philosophy of this martial art. Furthermore, this study also identified emerging challenges, including limited access to technology in areas with inadequate infrastructure and the lack of technology adaptation to the unique needs of Pencak Silat training (Widiastuti et al., 2022).

Furthermore, this study offers new value in evaluating the effectiveness of technology based on the athlete's competency level, namely amateurs compared to professionals. Previous studies often generalize the impact of technology without considering the variation in athlete abilities, creating a gap in understanding how technology can be adapted to the specific needs of each competency level (Anifah & Zuhrie, 2021, 2023; Lubis et al., 2022a; Subekti et al., 2021). This study also addresses the issue of technology accessibility, which is often a significant barrier in populations with low technological literacy or low socioeconomic status. This perspective is essential to ensure that technology adoption is not limited to professional athletes or areas with good infrastructure but is accessible to practitioners from various backgrounds.

This systematic literature review (SLR) examines the role of technological innovation in transforming Pencak Silat training, focusing on its potential to enhance physical, technical, and mental performance while preserving the cultural and philosophical roots of the art. The study aims to synthesize current research to identify the benefits, challenges, and opportunities associated with integrating technologies such as augmented reality (AR), virtual reality (VR), and wearables into training methodologies. The scope includes an analysis of the effectiveness of these technologies in enhancing skill acquisition, providing real-time feedback, and tailoring training for practitioners at varying levels of competence, from amateurs to professionals. The review also addresses the accessibility, affordability, and adaptability of technological tools to changing training needs. The review aims to provide actionable insights for practitioners, coaches, and policymakers by bridging traditional training practices with contemporary advancements, ensuring Pencak Silat's inclusive and sustainable evolution in modern technology.

Materials and Methods

This study employs a systematic literature review (SLR) to explore the technological innovations that have been developed, evaluate their advantages and disadvantages, and contextualize their application in Pencak Silat training. The review adopts a structured approach to ensure comprehensive coverage of the most relevant and high-quality research. This study aims to address the following questions to clarify the role of technology in the development of Pencak Silat martial arts:

- How does technology use impact the physical and technical performance of Pencak Silat athletes?
- What are the challenges in implementing modern technology in Pencak Silat training?
- Are there differences in the effectiveness of technology based on the level of competence (amateur vs professional)?

- What are the prospects for developing new technologies to enhance Pencak Silat training?

Database Selection

This systematic literature review utilizes Scopus as the sole database to identify relevant studies. Scopus is widely recognized for its extensive coverage and rigorous indexing of peer-reviewed literature across various disciplines, making it an ideal platform for conducting a comprehensive review in line with guidelines such as PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (Ferrara et al., 2023; Pandini, 2022; Ponce et al., 2022). Scopus provides access to a vast collection of high-quality articles, ensuring that the literature included in this review is both relevant and credible. The platform's robust search functionality enables researchers to efficiently identify studies aligned with the research objectives, minimizing the risk of publication bias and enhancing the systematic nature of the review process (Ertem & Aypay, 2023; Miseliūnaitė et al., 2022). In addition to its comprehensive literature coverage, Scopus offers tools for citation analysis and bibliometric studies. These tools are utilized to assess research trends and evaluate the impact of key studies in this field. Such analytical capabilities are critical for synthesizing existing knowledge and identifying gaps in the literature regarding technological innovations in Pencak Silat training (Corrales, 2023; Silva et al., 2021; Zgliczyńska & Kosińska-Kaczyńska, 2021).

Search Strategy

The literature search in this study was exclusively focused on the Scopus database, widely recognized as a trusted source for high-quality scientific literature. The search process was conducted using relevant keywords to identify studies that focus on technology in martial arts training, particularly Pencak Silat. For the Scopus search, the focus was on titles, abstracts, and keywords, using the following terms: ((“Pencak Silat training” AND “technology”) AND (“Augmented reality” AND “martial arts training”) AND (“Motion analysis” AND “Pencak Silat”) AND (Technological innovations in combat sports)). This approach ensures the inclusion of studies directly aligned with the research objectives, capturing the intersection of technological advancements and martial arts training methodologies.

Inclusion and Exclusion Criteria

Table 1 outlines the inclusion and exclusion criteria utilized in this study to guarantee the review's relevance and quality.

Table 1. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
• Studies should directly address technological aspects of Pencak Silat training, such as the effectiveness of training tools or technological methods. • Studies published in the last five to ten years were prioritized to reflect recent technological advances. • Empirical studies such as experimental, intervention, or developmental research that are relevant to the research topic.	• Studies that do not directly address technology in the context of Pencak Silat or other martial arts. • Opinion articles, editorials, or systematic reviews • Studies that do not provide sufficient data or methodology to be evaluated. • Only the most comprehensive publications were selected for studies that duplicated findings from other articles.

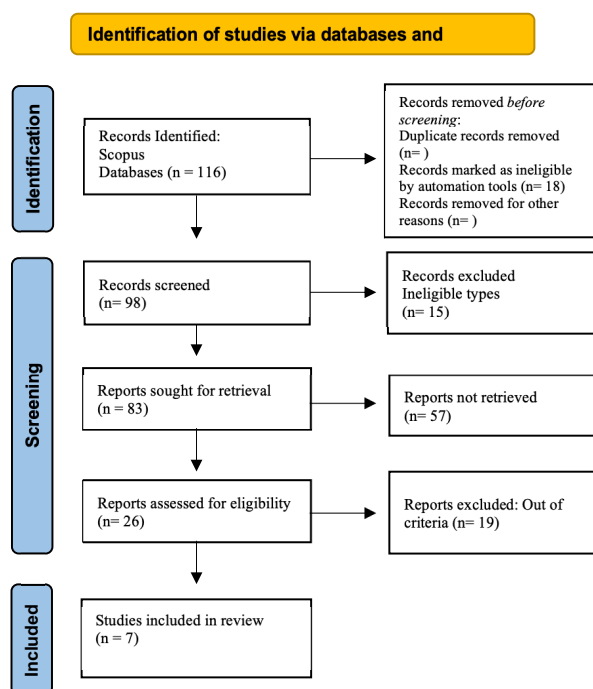


Fig. 1. PRISMA Flow

Study Selection Process

The study selection process followed the PRISMA framework to ensure a systematic and transparent approach. Initially, a comprehensive search was conducted in the Scopus database using pre-defined keywords. Duplicate and ineligible records were removed, and the remaining studies underwent a two-stage screening process. First, titles and abstracts were reviewed to exclude irrelevant or low-quality studies. Next, full-text articles were assessed for eligibility based on the inclusion criteria, focusing on relevance and recent technological advances in martial arts training. This ensured a robust data set for analysis.

Data Extraction and Synthesis

The data extraction process employed a structured approach to ensure comprehensive and consistent information collection from the selected studies. A standardized data extraction form was used to capture key details, including study objectives, methodologies, types of technologies examined, sample characteristics, and key findings. This process was conducted independently by two reviewers to minimize bias and ensure reliability, with discrepancies resolved through discussion or consultation with a third reviewer.

Thematic analysis was applied to synthesize the extracted data, allowing for the identification of recurring themes, trends, and challenges in the integration of technology into Pencak Silat training. Key themes included the effectiveness of augmented reality (AR) and virtual reality (VR) in skill acquisition, the utility of wearable devices in performance monitoring, and the accessibility challenges faced by practitioners. The synthesis process highlighted gaps in the literature, such as the limited focus on mental and philosophical training, providing a foundation for future research directions.

Limitations

This systematic literature review has several limitations that must be acknowledged. First, the review focuses exclusively on studies published in English, which may exclude valuable research in other languages. Second, using a single database, Scopus, while ensuring high-quality sources, may have overlooked relevant studies indexed

elsewhere. Third, the review considered publications from the last decade, potentially omitting earlier baseline studies. Furthermore, the variability in methodology and results across the selected studies poses challenges in synthesis and generalization. Finally, there is limited research on the use of technology in pencak silat training and the long-term impacts of technology use, highlighting areas that require further investigation.

Result and Discussion

Technology integration into Pencak Silat training has brought about transformative changes, increasing the effectiveness and precision of training methodologies. This review highlights the growing use of technology to enhance skill acquisition, performance monitoring, and tactical understanding. These innovations demonstrate a shift towards data-driven and interactive training approaches, benefiting practitioners at all skill levels.

Table 2. Technological Innovation in Pencak Silat Training

Author(s) (Year)	Study Title	Technologies Used	Impact on Performance	Implementation Challenges	Effectiveness Differences	Prospective Technologies
Omar Syarif et al. (2020)	Kinect-Based Application System Design for Pencak Silat Movement using SVMs	Kinect motion sensing and SVM	Improved movement detection accuracy (>90%)	Requires specific hardware and expertise for setup	Effective for all skill levels, especially beginners	AI-integrated motion sensing for advanced feedback
Muktiani et al. (2022)	Augmented Reality Mobile App-Based Multimedia Learning of Pencak Silat	Augmented Reality mobile app	Significant improvement in students' skills ($p < 0.05$)	AR adoption limited by device compatibility	More effective for younger learners in structured settings	AR with real-time feedback and gamification features
Usra et al. (2024)	Augmented Reality Training on Combat Sport	Augmented Reality training platform	Enhanced physical fitness (HDT, MST, $p < 0.05$) and technical performance	Training depends on user engagement and AR familiarity	More effective for experienced athletes (physical fitness gains)	Integration with AI for personalized training plans
Hasibuan et al. (2024)	Interactive Learning Media for Martial Arts Using Smart Apps Creator	Smart Apps Creator for mobile learning	Significant score improvement (pre-test: 7.6; post-test: 8.73, $p = 0.001$)	Limited to Android devices, requiring user proficiency	Universally effective across skill levels	Expansion to cross-platform compatibility (iOS, Web)
Rohayati et al. (2022)	Development of 3D VR Technology for Learning Pencak Silat Curriculum	3D Virtual Reality (VR)	Supported technical and cognitive skill development	High cost of VR setups and teacher training	More suitable for visual learners and language-focused instruction	Advanced VR simulations with haptic feedback
Sampoerna et al. (2021)	Virtual Reality Game for Introducing Pencak Silat	Virtual Reality rhythm game	High user satisfaction (78.61%) and immersion (77%)	Limited game content for diverse skill levels	Engages younger users more effectively	Integration with AI to enhance adaptive learning
Ihsan et al. (2024)	Sensor-Based Scoring System for the Fighting Category in Pencak Silat	Sensor-based scoring system	Increased scoring objectivity and reliability (ICC > 0.05)	Sensor calibration and durability in real competitions	Minimized scoring bias across athletes of different skill levels	Wearable sensors with real-time analytics

The technologies used include Augmented Reality (AR), Virtual Reality (VR), hardware-based sensor systems, mobile-based learning applications, and Kinect-based systems. These technologies support Pencak Silat movement learning, performance analysis, and objective assessments. These technologies generally show positive impacts such as increased movement detection accuracy (>90%), significant technical skills, physical fitness, and user satisfaction improvements. For example, AR improves technical skills and physical fitness, while VR provides an immersive experience that increases user interest. Research shows great potential for further development, such as the integration of AI, real-time feedback, and haptic technology for more realistic simulations. Wearable sensors have also been identified as a potential solution for improving analysis and training.

Research Question 1: Summary of Findings

Technology integration into Pencak Silat training has demonstrated transformative impacts on physical and technical performance. Technologies such as augmented reality (AR), sensor-based systems, and digital learning platforms have revolutionized training methodologies by providing real-time feedback, enhancing skill acquisition, and optimizing physical conditioning. For example, AR training has significantly improved physical fitness and technical skills, particularly among younger athletes, by offering an immersive and interactive learning environment (Usra et al., 2024). Similarly, digital platforms have proven effective in integrating theoretical and practical aspects of the sport, creating a comprehensive and engaging learning experience for athletes (Mulyana, 2024).

Sensor technologies have also emerged as critical tools in performance measurement, offering precise feedback on athletes' movements to refine techniques and assess performance more accurately. These systems are especially valuable when combined with traditional methods, as they help athletes achieve higher levels of physical and technical excellence (Ihsan et al., 2024; Maghribi, 2024). For instance, sensor-based scoring systems provide objective evaluations, address traditional judging methods' biases, and enhance competition fairness (Ihsan et al., 2024).

In addition to enhancing technical skills, technology has also contributed to optimizing physical conditioning. High-intensity interval training (HIIT), supported by technology-assisted programs, has significantly improved athletes' endurance and technical performance (Syarif et al., 2020; Usra et al., 2024; Zarya et al., 2023). Biomechanical tools such as Kinovea software have further enabled coaches to analyze athletes' movements effectively, resulting in improved techniques and performance (Irawan et al., 2021; Lubis et al., 2022; Sinulingga et al., 2023; Syaifullah et al., 2023).

Combining traditional training methods with innovative technologies offers a comprehensive approach to developing Pencak Silat athletes. While conventional methods instill cultural values and foundational skills, technology provides precision, objectivity, and efficiency in training. This dual approach ensures that athletes not only excel in physical and technical aspects but also maintain Pencak Silat's cultural and philosophical essence. Thus, the strategic application

of technology represents a vital step toward advancing this martial art's performance and training methodologies.

Research Question 2: Challenges in Implementing Modern Technology in Pencak Silat Training

Implementing modern technology in Pencak Silat training has several challenges that impact its widespread adoption and effectiveness. A significant obstacle is the resistance to change among coaches and athletes, many of whom prefer traditional training methods. This resistance often stems from a lack of familiarity with technological tools and skepticism regarding their benefits. The effectiveness of innovations such as augmented reality (AR) and digital learning platforms depends on the willingness of practitioners to embrace these methods, which requires targeted efforts to demonstrate their value and practicality (Muktiani et al., 2022; Mulyana, 2024).

Another significant challenge is the lack of infrastructure and resources, particularly in rural areas where Pencak Silat is deeply rooted. Inadequate access to reliable internet, modern devices, and training facilities limits the feasibility of implementing digital tools, further widening the gap between urban and rural practitioners (Yudaparmita et al., 2023). High financial costs associated with acquiring and maintaining advanced technologies such as sensor-based systems and VR setups also pose a barrier for many training centers, making affordability a critical issue for sustained implementation (Sampoerna et al., 2021).

The complexity of Pencak Silat's movements adds another layer of difficulty, requiring specialized technologies capable of accurately analyzing dynamic and intricate techniques. Developing and maintaining such systems can be resource-intensive and time-consuming, particularly for smaller organizations (Ihsan et al., 2024). Moreover, insufficient training for athletes and coaches to effectively utilize these technologies reduces their impact, emphasizing the need for tailored training programs to ensure proper usage and maximize benefits (Widiastuti et al., 2022).

Addressing these challenges requires a multifaceted approach. Increasing accessibility to technological resources, funding support for rural areas, and offering comprehensive training for practitioners are critical steps. Additionally, fostering awareness and understanding of the benefits of technology in improving physical and technical performance can help overcome resistance. By addressing these barriers, the integration of modern technology can achieve its full potential in advancing Pencak Silat training while preserving its cultural and traditional essence.

Research Question 3: Differences in the Effectiveness of Technology Based on the Level of Competence

The effectiveness of technology in Pencak Silat training demonstrates distinct variations between amateur and professional athletes due to differences in skill level, motivation, and access to resources. With their advanced physical and technical skills, professional athletes are often better positioned to maximize the benefits of augmented reality (AR) and sensor-based tools. For instance, AR has been shown to enhance technical performance and physical fitness, particularly for athletes with a well-developed

foundation of skills, as they can adapt more quickly to the advanced functionalities these tools offer (Usra et al., 2024). Additionally, professionals typically exhibit greater motivation and discipline, facilitating the seamless integration of new training methods into their routines (Nurhidayah, 2024).

In contrast, amateur athletes may face challenges in utilizing these technologies effectively. A lack of foundational skills and limited familiarity with the complexities of Pencak Silat training can hinder the adoption of advanced tools, reducing their potential impact (Ihsan et al., 2022). For example, sensor-based systems that require precise execution of movements might be more effective for professionals who can provide consistent inputs, whereas amateurs might struggle to meet these requirements. Similarly, the accessibility of technological resources is often limited for amateur athletes, particularly in settings where training facilities lack adequate funding or infrastructure (Mulyana, 2024).

Research also highlights differences in the psychological adaptability of athletes at varying levels. Professionals tend to exhibit higher engagement and commitment to training innovations, making them more receptive to technology-driven enhancements (Festiawan et al., 2024; Hasibuan et al., 2024). Conversely, amateur athletes may require additional motivation and simplified interfaces to effectively use these tools, underscoring the need for tailored solutions that address their specific learning and developmental needs (Anifah & Zuhrie, 2024; Burhanuddin et al., 2023; Halomoan et al., 2023). While technology holds promise for enhancing performance across all levels, its implementation must be adjusted to match the athlete's competence. Professionals can leverage advanced features for optimization, while amateurs benefit more from tools focused on foundational skill-building and accessibility. By addressing these differences, technological innovations can create equitable opportunities for improvement, fostering growth and excellence across all levels of Pencak Silat training.

Research Question 4: Prospects for Developing New Technologies to Enhance Pencak Silat Training

The future of Pencak Silat training is poised for significant advancements by integrating cutting-edge technologies, which promise to revolutionize traditional methodologies. Key innovations such as augmented reality (AR), virtual reality (VR), sensor-based systems, and artificial intelligence (AI) are paving the way for more effective, personalized, and engaging training experiences. AR and VR technologies are at the forefront of these advancements. AR applications enable athletes to visualize and practice complex movements in an immersive and controlled environment, enhancing technical skill acquisition (Muktiani et al., 2022; Usra et al., 2024). Similarly, VR provides an opportunity to simulate combat scenarios, allowing practitioners to refine their tactics and cognitive responses in lifelike yet safe conditions (Rohayati et al., 2022). These tools are especially valuable for younger athletes, combining interactive learning with technical development and making training more accessible and engaging (Mulyana, 2024).

Sensor-based systems are another promising area, offering precise measurement of performance metrics such

as kick speed, power, and movement accuracy (Damrah, 2023; Ihsan et al., 2024). These systems provide real-time feedback, allowing athletes to adjust their techniques dynamically during training sessions. Coaches can leverage the data collected by these sensors to design personalized training regimens tailored to each athlete's specific strengths and weaknesses (Maghribi, 2024). Artificial intelligence (AI) and machine learning further enhance the potential for personalized training. These technologies can analyze athletes' movement patterns and identify areas for improvement with greater precision than traditional methods. For example, AI-driven tools can predict injury risks based on biomechanical data, enabling preventive measures and safer training environments (Atqia & Suryani, 2023). IoT-enabled devices, such as pressure-sensitive mats, provide instant feedback on posture and execution, ensuring that athletes maintain proper form during practice (Ambarwati et al., 2024; Anifah & Zuhrie, 2024; Atqia & Suryani, 2023).

As these technologies continue to evolve, their integration into Pencak Silat training holds immense potential to bridge the gap between traditional practices and modern innovations. By combining cultural and philosophical values with technological advancements, future training methodologies can provide a holistic and inclusive approach, benefiting amateur and professional athletes. Ultimately, these developments are set to redefine the landscape of Pencak Silat, making it more effective, engaging, and accessible for practitioners worldwide.

The integration of technology in Pencak Silat training influences not only the physical and technical aspects of the sport but also its cultural and philosophical values. By embedding traditional teachings into digital tools, such as augmented reality (AR) and multimedia platforms, technology enhances the transmission of discipline, respect, and spiritual development central to Pencak Silat. These innovations create immersive learning environments that connect practitioners to the martial arts's core values while making these teachings accessible to a broader audience (Muktiani et al., 2022; Usra et al., 2024).

Maintaining cultural and philosophical values, which include lessons on discipline, respect, and spiritual development in technology-based training

AR and virtual reality (VR) provide engaging experiences where students can explore Pencak Silat's historical and cultural elements, helping them understand its philosophical underpinnings. For example, VR-based scenarios simulate real-life combat or training environments, enabling athletes to practice and embody values such as respect for opponents and self-discipline (Hadiana et al., 2022; Sampoerna et al., 2021). These tools improve physical training outcomes but also immerse practitioners in the cultural heritage of Pencak Silat, fostering a holistic appreciation of the art form.

Incorporating technology into structured training programs can instill ethical principles and life skills among young athletes. Studies suggest that technology-enhanced training, such as interactive multimedia platforms, supports the positive development of character traits such as responsibility and teamwork (Hadiana et al., 2022; Mulyana, 2024). Digital learning materials that highlight Pencak Silat's historical narratives and spiritual teachings encourage

deeper engagement with the philosophy of the art, ensuring that students gain a comprehensive understanding beyond physical performance.

Furthermore, using digital coaching platforms promotes a culture of continuous self-improvement. These platforms provide real-time feedback and facilitate detailed performance evaluations, encouraging athletes to refine their skills while respecting the traditions and techniques of Pencak Silat (Hasibuan et al., 2024; Ihsan, 2021; Sinulingga et al., 2023). Such advancements make it easier to balance innovation with preserving traditional values, ensuring that technology is a bridge rather than disrupting the martial arts legacy.

Community engagement is another critical aspect reinforced by technology in Pencak Silat training. Digital tools enable practitioners to connect with peers and mentors globally, fostering a sense of unity and shared cultural appreciation (Fahmi et al., 2024; Lanos et al., 2023). This strengthens interpersonal bonds among practitioners and ensures the continuity of collective values, such as mutual respect and support. While technology is primarily used to enhance physical and technical training, its influence on cultural and philosophical dimensions is equally significant. Through immersive tools, structured programs, and global connectivity, technology ensures that Pencak Silat remains a holistic practice, blending modern innovation with preserving its timeless values. This integration reaffirms Pencak Silat's role as not only a martial art but also a vehicle for cultural heritage and moral education.

Conclusions

Technology integration in Pencak Silat training has proven transformative, enhancing physical and technical performance while promoting engagement and learning efficiency. Tools such as augmented reality (AR), virtual reality (VR), and sensor-based systems have modernized traditional practices, enabling precise performance monitoring and immersive learning experiences. Despite these advancements, challenges such as accessibility, cost, and technology adaptation to meet diverse training needs persist. Addressing these issues is essential to ensure that the benefits of technology are equitably distributed among practitioners at all skill levels. Several steps should be taken to ensure the successful integration of technology in Pencak Silat training. First, efforts must be made to expand access to technology by providing funding and resources to rural and underprivileged areas, ensuring equitable opportunities for practitioners across all regions. Training tools should be tailored to the unique requirements of Pencak Silat, focusing on accommodating complex movements and preserving the cultural values inherent in martial arts. Additionally, structured training programs should be implemented for both coaches and athletes to maximize the effective use of technological tools in improving performance. Furthermore, there is a need to promote research, mainly longitudinal studies, to assess the long-term impacts of technology on skill retention, mental development, and the preservation of philosophical principles in Pencak Silat. Finally, fostering interdisciplinary collaboration between biomechanics, education, and cultural studies can help create holistic and innovative training methodologies that seamlessly integrate traditional and modern practices.

Conflict of Interest

All authors declare no conflict of interest.

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Інноваційні технології у тренуванні з Пенчак Сілату як складової культурної спадщини Індонезії: Систематичний огляд літератури

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

Реферат. Стаття: 10 с., 2 табл., 1 рис., 52 джерела.

Історія питання. Вивчення питання щодо інтеграції технологій у тренуваннях з Пенчак Сілату розглядається як важливий аспект, що акцентує увагу на потенціалі впровадження технологій з метою підвищення фізичної, технічної та розумової працездатності, водночас зберігаючи культурні та філософські цінності.

Мета дослідження. Дослідження мало на меті оцінити ефективність застосування доповненої реальності (ДР), віртуальної реальності (ВР) та сенсорних систем для покращення набуття навичок, моніторингу результативності та кастомізації тренувань. У дослідженні також розглядаються проблеми впровадження технологій і вивчається їх адаптованість до потреб практикуючих фахівців з різним рівнем кваліфікації.

Матеріали та методи. Систематичний огляд літератури (СОЛ) проведено відповідно до рекомендацій PRISMA. В якості основної бази даних використовувалась наукометрична база даних Scopus, з акцентом на дослідженнях, опублікованих протягом останнього десятиліття. Критерії включення визначали пріоритетність досліджень, присвячених інноваційним технологіям у тренуваннях з Пенчак Сілату, тоді як нерелевантні або низькоякісні дослідження були виключені. Збір даних здійснювався за допомогою стандартизованої форми та тематичного аналізу з метою визначення тенденцій, проблематики та наявних прогалин.

Результати. Отримані дані свідчать про значні технологічні досягнення в галузі доповненої і віртуальної реальності та сенсорних технологій, демонструючи їхню ефективність у підвищенні фізичної та технічної результативності. Однак продовжують існувати такі перешкоди, як висока вартість, обмежена доступність і потреба в індивідуальних рішеннях. Технології показали різну ефективність залежно від компетенції спортсмена: професіонали отримують більше переваг від розширених функціональних можливостей, тоді як для аматорів ефективними виявилися спеціалізовані інструменти.

Висновки. Технології революціонізували тренування з Пенчак Сілату, але їхня інтеграція вимагає розв'язання проблем, пов'язаних із доступністю та адаптацією. Подальші інновації мають поєднувати традиційні практики із сучасними досягненнями задля збереження культурних цінностей.

Ключові слова: Пенчак Сілат, доповнена реальність, віртуальна реальність, сенсорна технологія, інновації у тренуванні, систематичний огляд літератури.

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Review Article

The Influence of Performance Factors in Team Sports and Methodological Indications in Relation to the Performance Model: A Systematic Review

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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. The issue lies in whether or not there are common performance factors across different team sports. The objective of this review was to identify and analyze the key elements influencing physical performance in various team sports, which can be enhanced through training, respecting the performance model of each team sport.

Materials and methods. For the selection of articles, the Prisma method, Pubmed and Google Scholar search engines were used, and inclusion criteria were established. After conducting the initial search, a total of 596 articles were identified. These articles were then further screened through several stages to select 20 final articles that aligned with the theme.

Results. This review has highlighted important determinants of sports performance in common and uncommon among the different team sports analyzed and how they can be improved through training practices, taking into consideration the performance pattern of each team sport.

Conclusions. Achieving success in sport and the training of excellent players is increasingly dependent on the specificity of the coaching stimulus provided and how much it responds to the performance model of the team sport's type, and the competence of the coaching staff.

Keywords: performance analysis, conditional quality, performance model, practical applications.

Introduction

This review will analyse the performance factors, with a focus on what limits or enhances sports performance, and what practical indications can be used to improve that performance. In most team sports, sports performance requires more technical and tactical skills; while successful teams must also possess relevant physical skills (Bangsbo, 2015). The team sports examined, such as basketball, soccer, handball, rugby, and volleyball, require various physical skills and specific technical skills that are highly coordinative in order to achieve sporting success, as well as having to make quick decisions, during a competition, to solve complex technical and tactical motor tasks (Serpell et al., 2011). In team sports, there are factors such as reaction speed, acceleration, top speed, speed in whole-body changes of direction (Simonek et al., 2017) and agility that determine

a high value of sports performance (Little & Williams, 2005). However, there are slight differences in agility among players in team sports, this is probably due to demands on the quality of open skill movements (Belka et al., 2022). Running, in sports games, is characterized by continuous phases of acceleration and deceleration (Altavilla, 2020); in fact, players are required to repeatedly produce maximal or sub-maximal efforts with short recoveries (Bishop & Girard, 2013). Determinants in team sports are therefore the ability to accelerate and decelerate, change direction, jump, and repeat a series of actions at different speeds without reducing the quality of performance, and this is basic to sporting success (Jones et al., 2009). In fact, in soccer, accelerations and decelerations are found to be significant (Altavilla et al, 2017); in basketball and handball, changes of direction and jumps (Abdelkrim et al, 2007); in volleyball, jumps, landings, and explosive force (Tsoukos et al, 2019, D'Elia et al, 2021), while contrasts, thrusts, and tackles are found to be determinant mainly in rugby (Jones et al, 2015). As established in the literature, intense accelerations and decelerations (Delves

et al, 2021; Dalen et al, 2016) constitute a substantial part of the external workload and impose physiological and mechanical internal load demands on players (Burdon et al, 2017). However, accelerations have a higher metabolic cost (Hader et al., 2016), while decelerations have a higher mechanical load, probably caused by high force impact peaks (Verheul et al., 2019). Increasingly, systems capable of collecting data to assess the physical and technical-tactical performance of individual players and teams (Hoppe et al., 2018) are represented by Global Positioning System (GPS) and Match analysis (MA) for the detection of these variables and subsequent assessments. GPS and MA have assumed a very important role in sports games (Carling et al., 2009; McGarry et al., 2013); in fact, they are the most widely used devices for quantifying the quality, quantity of actions expressed, and characteristics of high-intensity accelerations and decelerations during matches (O'Donoghue, 2015).

The purpose of this review is to bring out and analyze common and non-common determinant aspects of physical performance among the team sports considered; which can be improved with specific training practices, within the performance model of each team sport.

Materials and Methods

The study was conducted through a review of the scientific literature aimed at identifying determinants capable of influencing performance in team sports. The PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) method was used, for which inclusion criteria were defined (Table 1). Scientific articles were searched through the following search engines: Pubmed and Google Scholar. The following keywords were searched: Performance analysis, conditional quality, team sport. Inclusiveness criteria were defined for article selection: year of publication, reviews and experimental studies, longitudinal studies, English language.

Table 1. Inclusion criteria

Web search engines	Pubmed and Google Scholar
Publishing period	2014-2023
keywords	Performance analysis, conditional quality, team sport.
Language	English
Type of article	Original research articles and/or review articles
Full text	Articles matched the purpose and/or topic of the research.

Results

After conducting the initial search, a total of 596 articles were identified. These articles were then further screened through several stages to select 20 final articles that aligned with the theme. Specifically, 13 reviews, 6 experimental studies and 1 longitudinal study were included. Table 2 shows, for each study, the authors, topic, method used, and results.

Discussion

To optimize the training process, it is essential to know what happens during a competition (Taylor et al, 2017).

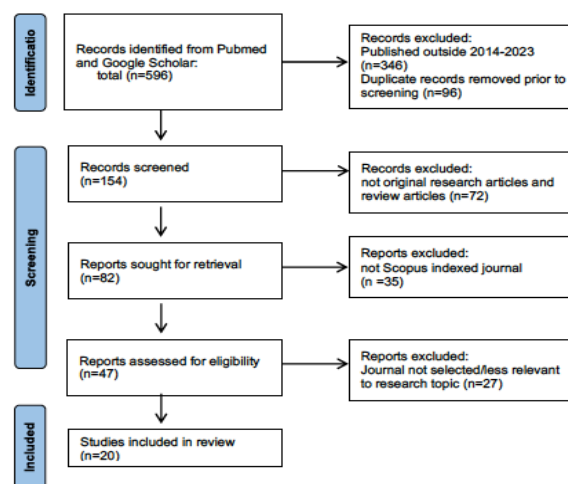


Fig. 1. PRISMA flowchart illustrating the item selection process

In order to gain such knowledge, it is necessary to analyze performance in team sports (Pino-Ortega et al, 2021), which analysis involves the study of different variables (technical, tactical, conditional), evaluation of training and competition workloads. Such a study provides quantitative knowledge about the level and technical, tactical, and behavioral characteristics of players in different team sports, such as in soccer, basketball, rugby, handball, and volleyball (Bangsbo et al., 2006; Svilar et al., 2018; Parmar et al., 2018; García-Sánchez et al., 2023; Silva et al., 2016).

Methodological Directions

Each team sport has its own performance model, where there is a certain level of strength, speed and endurance; therefore, training for each type of sport should reflect these differences. The most effective training methodology is one that approaches the functional model of competition (Cook, 2011). In order to implement an approach that is closest to the functional model of competition, it is essential to know what happens during the match; this allows the training process to be optimized. The continuous monitoring of sports performance (Esposito & Raiola, 2020) leads to the structuring of a performance model that meets the demands of a given team sport. We can define the performance model as a general framework of the specific characteristics of a sport: match times, energy metabolisms and type of movements.

Determining Factors

When a team or any athlete is training, it is necessary to know the performance pattern of his or her sport activity, from the perspective of internal load (e.g., heart rate, VO_2max , etc.) and external load (e.g., distance traveled, accelerations, decelerations, etc.); therefore, close monitoring of these specific actions during training and competition is appropriate for effective workload management (Impellizzeri et al., 2019). Tools such as devices, specific motor tests, and match analysis are essential for monitoring performance and optimizing workloads. Without neglecting other aspects of performance such as,

Table 2. Results of the literature review

N.	Authors	Topics	Method	Results
1	Pino-Ortega et al., 2021	Conditional quality and team sports	Systematic review	Design training tasks: Soccer, high level of aerobic endurance in combination with very intense and short actions. Basketball, high level of aerobic endurance with a high number of jumps and landings. Rugby, high speed of pace of play with intense efforts and collisions.
2	Taylor et al., 2017	Performance analysis and team sports	Systematic review	There is considerable variability in straight-line running and multidirectional demands among sports, competition levels, and sexes. Variability in sports demand data was found among sports, sexes, and age levels..
3	Impellizzeri et al., 2019	Performance analysis and team sports	Longitudinal study	When internal and external loads are implemented effectively, they can help coaches better control and optimize the training process.
4	Harper et al., 2019	Conditional quality and team sports	Systematic review and Meta-Analysis	19 studies, including seven team sports with a total of 469 participants (males with an average age of 18-29 years). High-intensity accelerations and decelerations are important elements of external biomechanical loading in team sports. In all team sports, apart from American Football, there was a higher frequency of high and very high intensity decelerations than accelerations. To ensure that elite players are optimally prepared for the high-intensity accelerations and decelerations required during games, it is essential that players are exposed to comparable demands under controlled training conditions.
5	Suchomel et al., 2016	Conditional quality and team sports	Literature review	Much research supports the idea that greater muscle strength can improve the ability to perform sports skills such as jumping, sprinting, and change-of-direction tasks. Muscle strength is strongly correlated with superior jumping, sprinting, and change of direction performance. Therefore, sports professionals should implement long-term training strategies that promote maximum muscle strength.
6	Hernández et al., 2021	Performance analysis and team sports	Experimental study	Results confirm the high reliability of the hexagon agility test. In addition, the performance was significantly related to the performance obtained in different physical performance measurements (change of direction, jump, and linear sprint tests).
7	Sattler et al., 2015	Conditional quality and team sports	Experimental study	The results underscore the importance of vertical jumps in many sports, including volleyball. From a practical point of view, the results suggest that professional male and female volleyball players perform better in vertical jumping, thus underscoring the importance of lower limb strength development and power qualities in volleyball players.
8	Spiteri et al., 2019	Conditional quality and team sports	Experimental study	The results provide evidence of the importance of lower extremity power, change of direction and agility in female basketball athletes to compete at high levels of play. Prescribing squats, power cleans or plyometric exercises and emphasizing the eccentric phase of the movement will develop in players the ability to tolerate a greater eccentric load by helping them decelerate and improving COD.
9	Silva et al., 2018	Performance analysis and team sports	Systematic review and Meta-analysis.	The review shows that a 72-hour post-match period is not sufficient to fully restore homeostatic balance (muscle damage, physical status, and well-being). Coaches must adjust the structure and content of training sessions during the 72-hour post-match intervention period to effectively manage the training load.
10	Gottlieb et al., 2021	Conditional quality and team sports	Literature review	For consistent, high-level performance throughout the season, conditioning is key. Aerobic capacity is significant in basketball for rapid recovery from repeated sprints and jumps. Therefore, coaches and athletic trainers must properly measure their players' aerobic capacity.

Table 2 (continued)

N.	Authors	Topics	Method	Results
11	Halouani et al., 2014	Performance analysis and team sports	A Brief Review	Small-sided games are widely used by coaches to develop technical and tactical skills and to improve the endurance of team sports players. In fact, higher exercise intensity is achieved with fewer players and larger field areas. Using different durations of practice seems to have minimal effect on exercise intensity. Regarding duration, the use of SSG 4×4 minutes seems to offer the most effective format.
12	Petway et al., 2020	Performance analysis and team sports	Systematic review	From the results of the present review, it appears that higher level players seem to be more efficient while moving around the field. Elite level players cover fewer distances, at lower average speeds and with lower HRmax and HRave during competition. However, they appear to have greater ability to move at higher speeds.
13	Ortega-Bacerra et al., 2018	Conditional quality and team sports	Experimental study	The results indicate that handball throwing speed is strongly associated with lower limb strength, although upper limb strength, jumping and sprinting skills also play a relevant role in throwing performance, suggesting the need for coaches to include appropriate strength programs to improve handball players' throwing.
14	Henderson et al., 2019	Conditional quality and team sports	Experimental study	The study examined the effect of a number of individual factors and characteristics on physical and technical performance values in rugby matches. The results showed that it is necessary to develop high aerobic and anaerobic fitness skills during preparatory periods to enable improved physical performance during matches.
15	Silva et al., 2019	Conditional quality and team sports	Systematic Review	Included studies have indicated that plyometric training appears to increase vertical jump performance, strength, horizontal jump performance, flexibility and agility/speed in volleyball players.
16	Lum et al., 2020	Conditional quality and team sports	Systematic Review	Increased muscle strength is associated with increased muscle power, improved jumping, sprinting and change of direction.
17	Nishiumi et al., 2023	Conditional quality and team sports	Systematic Review	This review examined studies that investigated the associations of eccentric force variables during jumping and lower limb eccentric force with vertical jump performance. Jump height is associated with sprinting and change-of-direction ability as well as competitive level in volleyball, soccer, and basketball. Improving eccentric muscle strength can contribute to vertical jump height.
18	Thurlow et al., 2023	Conditional quality and team sports	Systematic Review	Neuromuscular, physiological, and performance demands of Repeated sprint training (RST) are substantial. To amplify physiological demands and performance decrement, longer (> 30 m) and shorter sprint distances, rest between repetition (≤ 20 s) are recommended.
19	Loturco et al. (2018)	Conditional quality and team sports	Experimental study	The results have a significant impact on applied practice and research, as jump-based measurements can be considered as one of the most practical and useful approaches to assessing elite athletes. In addition, the results provide valuable information on the specific role played by vertically or horizontally directed movements in the distinct phases of sprint performance.
20	Delves et al., 2021)	Performance analysis and team sports	Systematic Review	Acceleration events in team sports research have been quantified predominantly through the use of effort counts, including time-related counts. Global positioning systems and now GNSS are the most common tracking systems used for quantifying acceleration in team sports athletes.

for example, the number and type of direction changes, total distance traveled and distance traveled at various speeds, and the number of accelerations and decelerations (Harper et al, 2019). An additional aspect to be monitored there is the performance trend between the first and second half of

the race, in which a decrease in performance by athletes can often be evidenced, so it is important to know the extent of it (Ortega et al, 2020). The performance model is used as a reference for monthly, weekly, daily and single exercise load. To summarize: team sports require athletes to have

highly developed speed, agility, muscular strength, power, and endurance (Suchomel et al., 2016a), but also the ability to repeatedly perform complex motor skills (e.g., passing, defending and countering, running, and jumping) under pressure and in fatigue (Rampinini et al., 2009). Finally, a programmatic goal of interest and in common among the different team sports analyzed is certainly the improvement of vertical jump performance; not surprisingly, jump height has a correlation with sprinting (Loturco et al., 2018) and change-of-direction ability (Hernández-Davó et al., 2021), both in volleyball (Sattler et al., 2015), soccer (Haugen et al., 2012), basketball (Spiteri et al., 2019) and rugby (Parmar et al., 2018). Knowledge of these common determinants, along with the specific performance model of each team sport, is useful in order to better define and design improved practices of different performance elements.

Correlations and Significant Effects

Strength: In most team sports there are several factors that influence performance (strength, speed, endurance, and highly coordinative specific motor skills) but without neglecting some aspects related to various expressions of strength (Gamble, 2013), sprinting ability, maximal oxygen consumption, and ability to recover from maximal efforts. There are strong correlations between the characteristics of strength training (maximum dynamic force, power) and sports skills such as speed, jumping and agility (Lum et al., 2020). An increase in muscle strength is consequently associated with an increase in muscle power, jumping ability, sprinting and change of direction (Nishiumi et al., 2023). In addition, strength training interventions improve performance in several other sports such as swimming (Crowley et al., 2017), cycling (Sunde et al., 2010) and endurance running (Lum, 2016).

Sprint: Sprint performance is an important factor (Izzo et al., 2020; Thurlow et al., 2023) and can often lead to athletic success (Winchester et al., 2008). Sprint performance has been shown to be an important determinant of winning actions in several team sports such as rugby, soccer, and basketball (Alemdaroğlu, 2012; Sims, 2017). The importance of sprint performance for athletes in team sports is evidenced by the observation that straight sprinting is a frequent action preceding a goal in soccer, a counterattack in basketball, a goal in rugby (Faude et al., 2012), etc. High sprint performance depends on stride length and stride frequency. Improvement in sprinting requires an increase in one or both of these parameters. Improvements in stride length are related to improvements in power, the latter in turn being directly related to maximal strength, elastic force and dynamic flexibility.

VO₂max: Other parameters to consider, for the purpose of sports performance in team sports, is maximum oxygen consumption (VO₂max) and the ability to recover from short, repeated high-intensity activities. The most widely accepted measure of aerobic capacity is VO₂max, which represents the maximum speed at which aerobic metabolism can supply energy (Castagna & D'Ottavio, 2001). The importance of VO₂max can be seen from an established correlation between VO₂max and distance traveled during team sports (Fernandes da Silva et al., 2010). Athletes with a high VO₂max are better able to maintain power during a

repeated sprint exercise (Glaister, 2005); moreover, detecting an increase in VO₂max is the most common method of ascertaining a training effect (Edge et al., 2006). In the literature, it has been shown that a high level of aerobic capacity is a prerequisite for superior anaerobic performance during prolonged intermittent activities (Seiler et al., 2013) and that a high level of aerobic capacity improves recovery after high-intensity exercise (Tomlin, 2001).

Practical Applications in Different Team Sports, Based on the Performance Model

Based on the performance model of each team sport, conditional-type training proposals should develop according to the following indications:

With regard to soccer, drills should involve a high level of aerobic endurance in combination with intense and short repetitive actions (Hostrup & Bangsbo, 2023). Physical conditioning in soccer should involve intermittent high-intensity actions (anaerobic endurance), such as fast movements, high metabolic load distance, sprint running, maximal speed (Redkva et al., 2018). Neuromuscular qualities, such as strength and power (jumps, acceleration, deceleration) and related to aerobic endurance (distance traveled, distance traveled less than 6 km/h, distance traveled between 21 and 24 km/h, metabolic power) provide a competitive advantage (Silva, 2022), as it predisposes players to better resistance to fatigue (Silva et al., 2017) and faster post-match recovery (Hader et al., 2019).

Basketball requires a good level of aerobic endurance, a large number of jumps, stops, changes of direction and short sprints at high intensity, in combination with passing and shooting. The game of basketball is characterized by short, intense periods of activity at medium to high frequency; such activity requires aerobic and anaerobic capabilities, both of which affect anaerobic performance (Gottlieb et al., 2021). Conditioning in basketball, involves speed above 18 km/h, maximal accelerations and decelerations, along with stops, restarts and jumps have been found to be major determinants of performance in basketball (Svilar et al., 2018). Because players' movements are carried out over small spaces, this requires a higher number of accelerations/decelerations and more intense movements (Halouani et al., 2014); in addition, elite players appear to be more efficient and effective while moving around the court (Petway et al., 2020).

Handball being characterized by motor skills such as speed, explosive power, endurance and strength, involves acceleration, deceleration and changes of direction in relation to the ball and the opponent, results in high levels of internal and external load (Ortega-Bacerra et al., 2018). Identifying these specific requirements is a key aspect in designing specific training programs, such as plyometric training (Hamami et al., 2019). Programming, therefore, drills on a good level of aerobic endurance is appropriate, such as including sessions for upper limb strength development for passing and shooting, and lower limbs for jumping (Povoas et al., 2012). Precisely because, in handball, throwing speed is strongly associated with both lower limb and upper limb strength; finally, jumping and sprinting skills should not be neglected, which play a relevant role in throwing performance.

Rugby requires a good level of aerobic endurance and strength, in the development of the game needs to maintain

a high pace of play (high time of ball possession), perform high-intensity drills in combination with countering, pushing and tackling (Colomer et al. 2020). The most relevant determinants for rugby players turn out to be aerobic/anaerobic endurance (perceived exertion rating, increased weekly load, heart rate, high speed distance), in combination with impacts, collisions, and tackles that are equally important (Henderson et al., 2019).

Volleyball is a very explosive and predominantly anaerobic intense sport in which anthropometric and somatotypical characteristics have a strong influence. This sports discipline combines explosive movements in vertical and horizontal directions, with short recovery times (Gabbett & Georgieff, 2007, Penna et al, 2023) that requires the development of endurance, speed and strength in the following expressions: explosive, resistant and reactive-elastic, endurance and speed, in which plyometric training is widely used (Silva et al., 2019). From the analysis of the performance model, it is clear that the energy system mainly involved is the alternating aerobic-anaerobic system (D'Isanto et al, 2018), with prevalence of the anaerobic-attacid one. The aspects that most characterize volleyball players are jumping ability, power and strength. Plyometric training, for example, is used to improve performance on jumps (Pereira et al, 2015). In one study (De Villarreal et al, 2009), in which free-body plyometric exercises, countermovement jumps, deep jumps and squats were used, they resulted in an increase in vertical jump height of up to 15 percent.

Conclusions

This review has highlighted important determinants of sports performance in common and uncommon among the different team sports analyzed and how they can be improved through training practices, taking into consideration the performance pattern of each team sport. In recent years, there has been a trend toward training players who are increasingly faster (maximum running speed, short and more explosive sprints) and with greater speed in performing specific techniques (e.g., passing and shooting speed). Therefore, it is necessary to resort to the use of up-to-date, evidence-based training practices and sophisticated monitoring tools. Achieving success in sport and the training of excellent players is increasingly dependent on the specificity of the coaching stimulus provided (e.g., drills adhering to the performance model of a given sport), how much more responsive to the performance model of the type of team sport, and the competence of the coaching staff (e.g., the mastery of the coach and his or her staff in the management and analysis of the match and training load). In the near future, the focus of the research could attend to individual sports, while a limitation of this review may be the use of only a few search engines.

Conflict of Interest

The author declares that he has no conflict of interest.

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Вплив факторів результативності у командних видах спорту та методологічні вказівки щодо моделі результативності: Систематичний огляд

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

Реферат. Стаття: 10 с., 2 табл., 1 рис., 78 джерел.

Мета дослідження. Суть питання полягає в тому, чи існують спільні фактори результативності серед різних командних видів спорту. Метою цього огляду було визначити та проаналізувати ключові елементи, що впливають на фізичну працездатність у різних командних видах спорту, які можна поліпшити за допомогою тренувань, дотримуючись моделі результативності кожного командного виду спорту.

Матеріали та методи. Для відбору наукових публікацій застосовано метод, що відповідає стандарту PRISMA («Переважні елементи звітування для систематичного огляду та метааналізу»), пошукові системи Pubmed і Google Scholar, а також встановлено критерії включення. Після проведення первинного пошуку загалом було виявлено 596 публікацій. Наступний крок передбачав подальшу перевірку статей в кілька етапів з метою відбору 20 остаточних публікацій, які відповідали тематиці дослідження.

Результати. У представленому огляді висвітлено важливі детермінанти спортивної результативності, які є спільними та відмінними серед різних проаналізованих командних видів спорту, а також способи їх покращення за допомогою тренувальних практик, враховуючи модель результативності кожного командного виду спорту.

Висновки. Досягнення успішних результатів у спорті та підготовка висококласних гравців дедалі більше залежить від специфіки наданих тренерських стимулів, а також від того, наскільки це відповідає моделі результативності типу командного виду спорту та компетентності тренерського складу.

Ключові слова: аналіз результативності, умовна якість, модель результативності, практичне застосування.

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Review Article

Identifying the Evolution of Learning Methods in Physical Education: A Systematic Review of Modern Approaches and Digital Integration

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Abstract

Background. The learning process in physical education requires an appropriate and effective learning method. It is incumbent upon physical education teachers to determine learning methods that take into account the conditions of their students.

Objectives. The objective of this study was to conduct a systematic review of the development of learning methods that have occurred in physical education so far.

Materials and methods. The present study used four databases: SCOPUS, Google Scholar, OpenAlex, and Crossref as research data. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses method was applied in the identification of research data. Furthermore, it was also conducted a keyword analysis using VosViewer software. In addition, a literature review was conducted to provide a more comprehensive understanding of the topics that have been researched.

Results. A total of 5358 articles were identified as systematic reviews in this study. The results of the systematic review showed that research has undergone significant development. On the other hand, learning methods in physical education have also successfully integrated digital technology. The development that occurs is characterised by traditional learning methods turning into modern learning methods. The integration of technology in modern learning methods has a positive impact on students and teachers.

Conclusions. The findings indicate that the development of learning methods in physical education has evolved very significantly. These developments are still needed in the digitalisation aspect, so that the methods applied are more futuristic.

Keywords: learning methods, learning models, pedagogy, students, teacher.

Introduction

Physical Education (PE) is an important part of the school curriculum that supports students to stay fit through physical activity and a healthy lifestyle (Ali et al., 2022). PE also plays a role in shaping social values such as discipline, co-operation and sportsmanship that are beneficial for students. In Indonesia, PE is one of the compulsory subjects

since students are in primary school (Li et al., 2024). The establishment of PE as a compulsory subject, proves the importance of PE in supporting the development of a child holistically (Hao & Wang, 2024). The development that includes cognitive, movement skills, and affective aspects can be developed through an effective PE learning process (Aliriad et al., 2024).

The effective learning process, of course, is closely related to how a teacher transfers knowledge to students (Williyanto et al., 2020). Choosing the right learning method is one of the keys to a successful learning process (Rihatno et al., 2024). On the other hand, a deep understanding of student characteristics is needed in determining a learning

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method (Kirch et al., 2021). It is important for teachers to recognise students' personalities so that the learning process can run efficiently (Zhao & Zhao, 2022). Students who receive knowledge and teachers who impart knowledge can enjoy the learning process (Wittwer et al., 2024). Thus, the learning objectives that have been set by a teacher can be achieved easily (Redelius et al., 2015).

Along with the times, there have been many techniques or ways to approach teachers to students (Magonde et al., 2017). The scientific approach began to be developed with the aim of students being able to train critical thinking during the learning process (Sakti et al., 2021). The development of the cooperative approach, which is designed with the aim of training students' social skills without leaving the material being studied (Luna-Vazquez & Estrada-Oliver, 2024). Social interaction when working in a group is a characteristic of this cooperative approach (Silva et al., 2021). The integration of these two approaches creates a critical learning process by creating a space for discussion between students (C. Hidayat et al., 2023).

The development and adjustment of learning methods continue to occur in order to achieve a quality learning process (Pomatahu et al., 2023). So far, the learning methods used in PE learning vary. It depends on school policy, teacher competence, available facilities and infrastructure, and the characteristics of the students in the school (Yakub et al., 2019). The evolution from conventional to modern learning methods has had a significant positive impact on the quality of learning (Wang, 2022). In the past, learning only focused on the teacher, resulting in students becoming passive when participating in learning (Crum, 1993). However, nowadays learning is more focused on student activeness or better known as "student centred learning" (Risyanto et al., 2024).

This research aims to systematically review the development of learning methods that have been applied in physical education. Analysis of research data conducted systematically and comprehensively is expected to provide a new understanding of the development of learning methods in physical education. This allows for innovation in physical education learning methods, so that the learning process becomes more attractive again. Through the development of appropriate and varied methods, adaptations in the learning process will be easier to implement. Thus, a teacher will always have many strategies in delivering the material in various conditions and situations.

Materials and Methods

Study Design

This study is a systematic review study that uses the Preferred Reporting Items for Systematic Review and Meta-Analyst (PRISMA) method in processing the identified and screened research data. In using this method, researchers collected research data based on four journal databases. These databases are SCOPUS, Google Scholar, Crossref, and OpenAlex. The researcher used the keywords "learning", "methods or models", and "physical education", when identifying the research data. The identification was carried out on 1st January 2025. In the identification process, the researcher set the inclusion and exclusion criteria in this study. The inclusion criteria in this study are research documents written in the form of articles. While

the exclusion criteria are research documents that are not written in the form of articles, such as books, conference papers, reviews, and others.

Study Procedure

Researchers use Publish or Perish (PoP) software as a research data search engine, because this software is able to provide information on the year, citation, and type of research. Thus, the screening process can be done more efficiently. However, there is a limitation in the number of documents identified, which is only limited to 1000. Specifically for the SCOPUS database, researchers directly carried out the identification process on the SCOPUS website. This is because through this website, researchers are able to obtain more research data. Then, in order to avoid gaps in research data, researchers exported the SCOPUS identification data into PoP. Thus, research data can be accumulated effectively, and the screening process can be carried out efficiently with the help of PoP software.

On the other hand, researchers also used VosViewer software to conduct keyword analysis based on research data from SCOPUS. Researchers chose the database because only SCOPUS is able to provide research data that is suitable and effective for keyword analysis using VosViewer. Researchers screened inappropriate keywords through the software, such as "article", "statistic", "human", and many more. This was done in order to present the analysis results in accordance with the objectives of this study.

A literature review was also conducted in this study to provide a more comprehensive understanding. This review is based on articles that have the highest number of citations. The highest number of citations represents the quality of the article as a reference for other researchers in developing new research. According to the researchers, through the selection of articles with the highest number of citations, it will provide a more complete and thorough discussion of topics that are often researched. Thus, it is possible that new interesting research gaps will be found in the future.

Results

The research implements the PRISMA method which is presented through the flow in Figure 1. Based on the presentation of the figure (Figure 1), the identification process was carried out through four databases with a total document acquisition of 6985 documents. This number is the result of identification in various forms of documents such as books, reviews, and conference papers, not just articles. The inclusion criteria set previously, obtained documents that were not in the form of articles as many as 1627 documents. As for documents in the form of articles, 5358 articles were identified (Table 1). The documents in the form of articles were used as research data to conduct a systematic review. The articles will be sorted based on the most citations using PoP, which then selected a number of 10 articles with the most citations. Then, as a result of the ranking, a literature review will be conducted.

Research Publication of Learning Methods in Physical Education Research

The distribution of research publications on learning methods in physical education (PE) over time is shown in

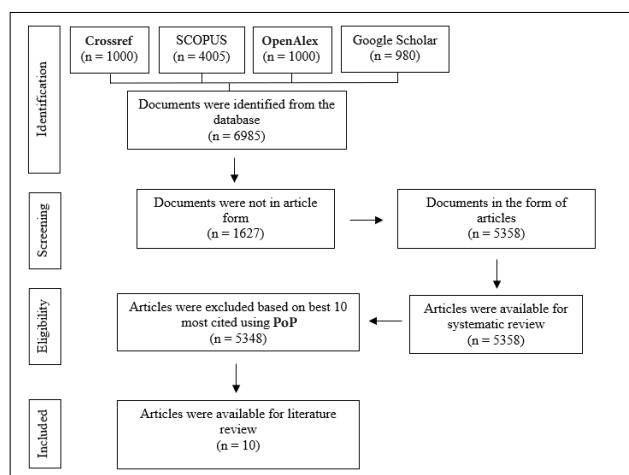


Fig. 1. PRISMA flowchart of the article selection process

Table 1. Research database of learning methods in physical education research

	Source	Paper	Cites	Cites/Year	H-Index
	SCOPUS	3255	43986	505.89	84
	OpenAlex	753	1605352	12640.57	753
	Crossref	434	4634	36.78	34
	Google Scholar	916	139881	1472.43	179
Total		5358	1793853	13183.24	

table 2. The table highlights the number of papers, total citations, average citations per paper, and their percentage of the total (Table 2). Early research (1896–1950) accounted for a negligible proportion of publications (less than 1%), with minimal citations, reflecting the nascent stage of academic focus on PE learning methods during this period. Despite low output, a few early works, such as those in 1926–1930 and 1951–1955, received significant citations, suggesting seminal contributions that have influenced the field.

From 1961 to 1990, the field presented a gradual increase in publications and citations, with notable milestones in 1961–1965 and 1986–1990. These periods reflect the growing academic interest and recognition of PE as a significant research area, coinciding with advancements in education and physical sciences. For example, the average citations during 1961–1965 (12077.00) and 1986–1990 (82007.50) highlight impactful studies that shaped future research directions. However, it was not until the 1990's that research activity surged significantly, with publications increasing to 129 (1991–1995) and 193 (1996–2000), accompanied by a corresponding rise in citations.

The most notable growth occurred from 2001 onwards, with exponential increases in both publication frequency and citation impact. The period from 2016–2020 alone accounted for 23.91% of total publications, while 2021–2025

saw the highest contribution, with 1979 papers (36.94%). This surge reflects the expanding importance of PE learning methods in addressing modern educational, technological, and health challenges. The consistent rise in average citations also suggests improved quality and global relevance of research in this domain. Overall, the table highlights how research in PE learning methods has evolved from foundational studies to a prominent, interdisciplinary field with substantial academic and practical contributions.

Table 2. Research publication of learning methods in physical education research

Year of Publication	Paper	Cites	Average	Percentage (%)
1896-1900	2	1165	583.50	0.04
1901-1905	1	0	0.50	0.02
1906-1910	1	1	1.00	0.02
1911-1915	2	0	1.00	0.04
1916-1920	2	0	1.00	0.04
1921-1925	2	1	1.50	0.04
1926-1930	4	1254	629.00	0.07
1931-1935	8	7	7.50	0.15
1936-1940	1	0	0.50	0.02
1941-1945	1	0	0.50	0.02
1946-1950	0	0	0.00	0.00
1951-1955	4	1628	816.00	0.07
1956-1960	5	1009	507.00	0.09
1961-1965	10	24144	12077.00	0.19
1966-1970	18	7784	3901.00	0.34
1971-1975	18	24065	12041.50	0.34
1976-1980	48	62406	31227.00	0.90
1981-1985	59	68794	34426.50	1.10
1986-1990	76	163939	82007.50	1.42
1991-1995	129	118656	59392.50	2.41
1996-2000	193	259682	129937.50	3.60
2001-2005	315	318372	159343.50	5.88
2006-2010	446	306876	153661.00	8.32
2011-2015	753	233438	117095.50	14.05
2016-2020	1281	162674	81977.50	23.91
2021-2025	1979	37958	19968.50	36.94
Total	5358	1793853	899605.50	100.00

The bar chart depicts the distribution of publications over time, illustrating a sharp increase in academic outputs in recent years (Figure 2). Between 1896 and the early 2000s, the number of publications remained relatively low, with only single-digit contributions per time period. This gradual accumulation of research suggests limited attention to the topic during these early decades. However, starting from the 2000s, there is a noticeable upward trend, reflecting the growing relevance of the subject matter in academic discourse.

The most significant surge occurs between 2012 and 2025, with publications skyrocketing from 753 in 2012–2021 to 1197 (including 197 for 2022–2025). This steep rise demonstrates an intensified interest and urgency in exploring the topic, likely driven by advancements in technology and its impact on governance and societal systems. The pattern signifies a shift in research priorities, as digital transformation and related fields have become increasingly central to addressing contemporary challenges. This growth underlines the evolving role of research in responding to technological and societal shifts.

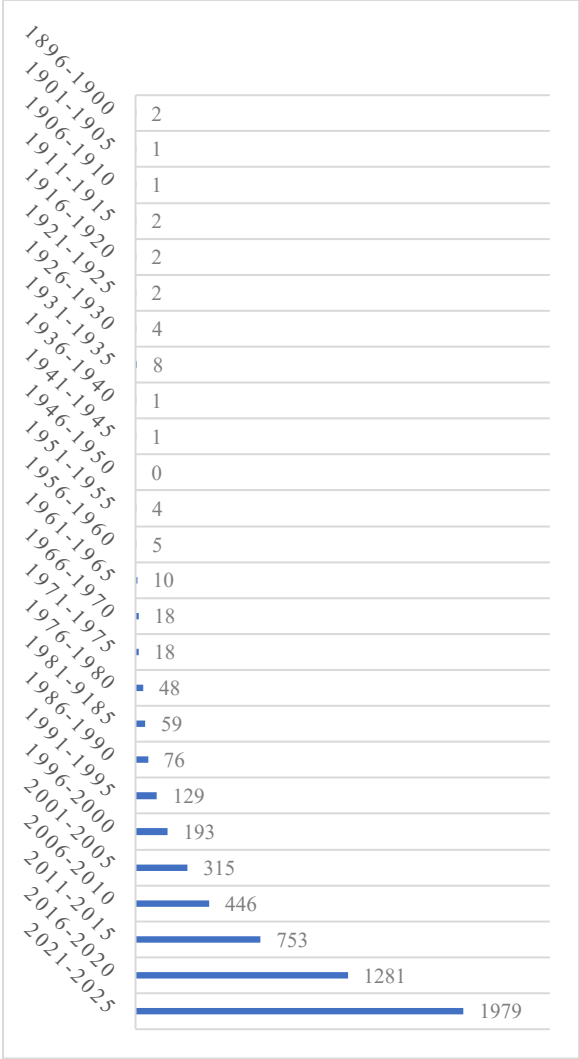


Fig. 2. Graphic of Research Publication

Subject Area of Learning Methods in Physical Education

Research on learning methods in PE shows an expansion into various subject areas related to learning methods. The presentation of table 3 is the result of identification from the SCOPUS database, because only through this database the researcher is able to know the number of publications made along with the number of citations. Based on the identification results, it presents that “social science” is one of the dominating subjects with 1825 articles published. This phenomenon occurs because the learning process in physical education cannot be separated from social science.

The science is characterised by the interaction between teachers and students and students with peers. This triggers the expansion of the subject area into social science. The subjects “health professions”, “medicine”, and “psychology”, are indicative of the expansion into the realm of health. The existence of learning related to health science and disease prevention, allows for expansion in the subject area. Theories related to Self Determination Theory (SDT) in PE, is one indication of the emergence of the subject area “psychology”. Other subjects such as “engineering”, “mathematics”, “environmental sciences”, “biochemistry, genetics and molecular biology”, and “arts and humanities”, are evidence that learning methods in physical education have shifted to modern learning methods, not just conventional ones. Integration with Science Technology Engineering and Mathematics (STEM) supports the expansion in these subject areas.

Table 3. Top 10 subject area of learning methods in physical education research

Subject area	f	Total Cited	Average Cited
Social Science	1865	27305	14585.00
Health Professions	1628	24805	13216.50
Medicine	1617	27672	14644.50
Computer Science	412	3034	1723.00
Psychology	310	4825	2567.50
Engineering	262	1498	880.00
Mathematics	170	506	338.00
Environmental Sciences	136	1545	840.50
Biochemistry, Genetics and Molecular Biology	136	851	493.50
Arts and Humanities	81	1139	610.00
Total	6617	93180	49898.50

Affiliations of Learning Methods in Physical Education Research

Affiliates are universities that contribute to developing teaching methods in PE through their research and innovations (Table 4). In table 4, the results of research data identification are the same as the previous sub-section, or have the same database source as table 3, namely SCOPUS. Yogyakarta State University occupies the first position with 67 articles published. This shows the high interest of lecturers or researchers in researching related to PE learning methods at the university. Although the number of article publications shown is extraordinary, the number of citations shown is the least compared to other affiliations.

The number of citations reflects how the development of research conducted still requires evaluation and review in order to be able to provide new ideas or innovations for other researchers. Innovative ideas or interesting findings will generate significant citations, as they are in line with the quality of the findings of the research. Loughborough University only contributed 37 articles, but the citations displayed were quite a lot with a total of 1796 citations. Loughborough University is a leading university that is well known in the field of sports science. So, the research

conducted is able to make a significant contribution in the field of sports, especially in learning methods in PE.

Table 4. Top 10 affiliations of learning methods in physical education research

Affiliation	f	Total Cited	Average Cited
Universitas Negeri Yogyakarta	67	328	197.50
University of Limerick	61	2042	1051.50
Universidad de Oviedo	58	1199	628.50
Universidad de Granada	55	815	435.00
Universidad de Extremadura	46	837	441.50
Universidad de Castilla-La Mancha	43	687	365.00
Universitat de València	42	699	370.50
Universidad de Murcia	39	621	330.00
Loughborough University	37	1796	916.50
The Ohio State University	37	922	479.50
Total	485	9946	5215.50

Countries Contributed of Learning Methods in Physical Education Research

The development of learning methods in PE has spread to various countries around the world (Figure 3). The visualisation shown in Figure 3, proves the almost even distribution of research in various regions. However, more intensive research still needs to be done by countries in the African continent, especially in the Central African region. The American continent shows the dominance of contributions in learning methods research in PE, marked by the number of article publications as many as 593 articles through the United States of America (USA). Asian countries also contributed significantly, such as China with 554 articles and Indonesia with 215 articles. On the other hand, countries in Europe such as the United Kingdom (UK) and Spain contributed 234 articles and 443 articles.

These remarkable contributions are due to the innovative education system, especially when applying learning methods in PE. Collaboration between researchers carried out by these countries is also able to make significant contributions through research cooperation. The availability of facilities and infrastructure is one of the keys for research in these countries to develop optimally.

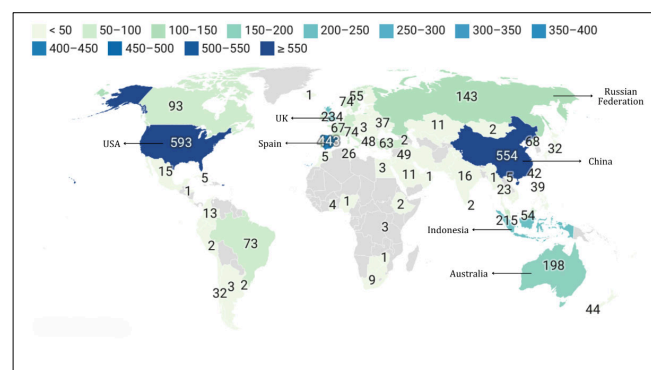


Fig. 3. Map of countries contribution

Keyword Analysis of Learning Methods in Physical Education

Keyword analysis was conducted with the aim of knowing the research topics related to learning methods in PE from the beginning of its development to the present. Through VosViewer keyword analysis software, the results of the analysis can be visualised and the correlation between keywords can be identified. The colour gradation displayed means the development that occurred in a certain period of time or several years. The visualisation displayed shows a significant distribution or development of keywords between 2014 and 2022, this is not an indication that there is no research development outside the year range. The range of years shown, shows the existence of keywords in research on learning methods in PE that are more varied.

The years 2014-2016 show the emergence of the keywords “motor skills”, “training”, “technique”, and others which are evidence that learning methods at that time still focused on the skills of a student. The learning process is still conventional or monotonous, the methods used are less attractive and innovative. At that time, it can be assumed that learning was still focused on the teacher, or better known as “teacher centre”. However, the keyword “videorecording” is an indication of a shift from conventional learning methods to modern learning methods.

Entering 2017-2020, learning methods began to transition from conventional, to more modern. Learning with the “teacher centre” method began to be abandoned, and switched to “student centre” or student-centred. Keywords such as “problem-based learning”, “cooperative learning”, and “tqfu” are evidence that learning methods in PE have shifted to become more innovative. On the other hand, this year also saw an increase in teacher competence, which is necessary in providing a more meaningful learning process. The emergence of the keywords “professional learning”, “professional development”, “pedagogy”, “pedagogics”, and “pedagogical models”, is an indication of an increase in the quality of PE educators or teachers during these times.

Learning methods in PE continued to modernise in 2021-present. This modernisation process was supported by the Covid-19 pandemic in 2021-2023. The existence of Covid-19 at that time, resulted in the learning process taking place online and demanded the use of digital media. Digitalisation in the learning process occurs indirectly, especially in the implementation of learning methods. Keywords such as “distance learning”, “blended learning”, “online learning”, and “e-learning”, are evidence for these statements. In addition, digitisation in learning methods continues until it finally applies modern technology in the PE learning process. “virtual reality technology” and “augmented reality” are indications that learning methods in PE have begun to integrate Virtual Reality (VR) and Augmented Reality (AR) technology.

Literature Review of Learning Methods in Physical Education Research

This literature review was conducted based on the results of PRISMA screening and ranking through PoP software. The results obtained 10 articles with the highest number of citations in research on learning methods in PE (Table 5). The results of this literature review showed that 5 articles

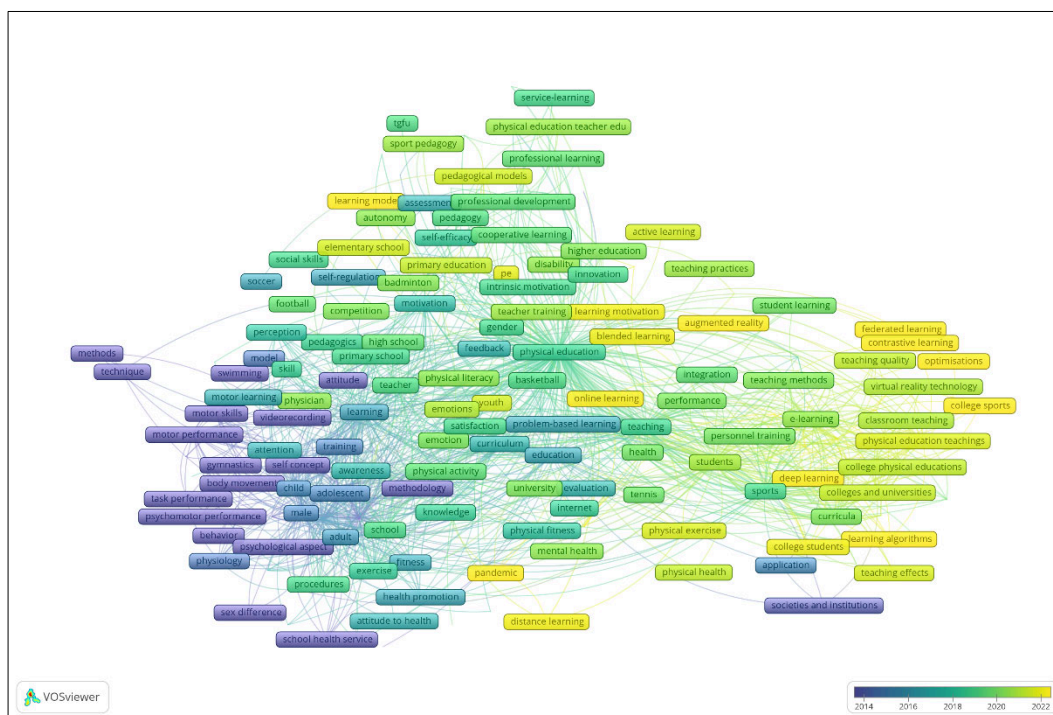


Fig. 4. Keyword analysis of learning methods in physical education

were written using experimental methods, 1 literature review article, 1 correlational study, 2 systematic reviews, and 1 Research and Development (RnD).

Research by Casey & Goodyear, (2015) explained that cooperative learning methods are effective in training skills, knowledge, social, and attitudes. However, for the attitude domain Casey & Goodyear, (2015) suggested that more intense research should be conducted on that domain. In line with this research, Bores-Garcia et al. (2021) conducted a systematic review research and obtained the results that research related to cooperative learning methods focuses more on the social domain. Social domain and attitude are two domains that are interrelated in the learning process. Bores-Garcia et al. (2021) proved that in the years following the study by Casey & Goodyear (2015), research on cooperative learning methods focused more on the social domain.

Systematic review research by Barba-Martin et al. (2020) identified that the Teaching Games for Understanding (TGfU) learning method is often used in the process of learning skills and knowledge. The use of TGfU is considered effective in providing a fun and interesting learning process. This is evidenced through experimental research by Gil-Arias et al., (2017) which shows that students are more motivated and enjoy learning PE. Similar methods such as gamification researched by Fernandez-Rio et al., (2020), proved that learning methods that include game elements can provide meaningful PE learning and improve academic performance.

Technology-based PE teaching using video analysis methods has a positive impact on students in providing a more comprehensive understanding. This is evidenced through research by Casey & Jones, (2011), and shows other results that through this method, student engagement can

be improved. On the other hand, online or hybrid learning methods in PE were also conducted during the Covid-19 pandemic. The development research by Yu & Jee, (2020), proved that PE learning can be done online. However, this requires the role of professional PE teachers.

The studies that have the highest number of citations are a means of determining the research trends that have developed. Learning methods such as cooperative, TGfU, gamification, online, hybrid, and modern technology-based, are evidence that current research often develops or researches these topics. Through the number of citations displayed and the research topics described, it will provide innovation for future research in determining relevant research topics in the future.

Discussion

This research aims to systematically review the development of learning methods in PE over the years. The analysis carried out regarding the development of learning methods shows the results of a very significant development. The development process of learning methods in PE has shifted from traditional methods to more up-to-date methods. The emergence of aspects related to digital technology in the learning process is proof that the transition and development really happened.

The results of the systematic review show that in the physical education process, the most commonly used learning methods are cooperative and game-based learning methods, such as gamification or TGfU. However, other methods such as problem-based learning and e-learning are also used in the PE learning process. The researcher has summarized the research results and formulated them into four discussion topics, which are explained as follows.

Table 5. Literature review of top 10 most cited research

Author	Total cited	Research Purposes	Methods	Results
Casey & Goodyear, 2015	472	To investigate the empirical studies on the performance of learning in the physical, cognitive, social, and affective domains that have been published regarding the application of cooperative learning in physical education.	Literature Review	The research concluded that although learning took place in all four domains, the physical, cognitive, and social domains showed the most significant benefits, and anecdotal reports of affective learning made it evident that further effort is needed in this area.
Fernandez-Rio et al., 2020	226	To investigate the potential experience effects on teachers and students as well as the application of gamification in physical education.	Pre-Experimental Study	The components of gamification can be used to create meaningful physical education experiences for students of various educational levels, from teachers with varying levels of gamification knowledge to students from diverse social and educational backgrounds.
Bores-García et al., 2021	222	To review systematically thorough analysis of the studies that have been done on cooperative learning in physical education throughout the past five years (2014–2019).	Systematic Review	The findings indicated that secondary education primarily short-term interventions were the primary focus of the investigation. In terms of the study's objectives, social learning which focused on motivation, group dynamics, and teacher-student interaction was evaluated the most.
Gil-Arias et al., 2017	217	To examine how students perceive different facets of their motivation to participate in physical education when a hybrid TGfU/SE unit is used instead of direct teaching.	Experimental Study	When taught utilizing the hybrid paradigm, the two groups demonstrated notable increases in autonomy, competence, and enjoyment, irrespective of the order of intervention. Rather, there were no appreciable gains in one group's autonomous motivation, relatedness, or intention to engage in physical activity.
Casey & Jones, 2011	204	To investigate how video technology can help students participate in physical education.	Experimental Study	The ability of video technology to increase student engagement and, in turn, imply that this level of dedication aided students in developing comprehension that went beyond technical imitation and toward logical and reasoned student explorations surrounding their learning. It also made students feel less excluded and encouraged them to participate more actively in their education.
Fernandez-Rio et al., 2020	201	To examine how gamification in physical education affects university students' academic performance and motivation.	Experimental Study	Despite the fact that intrinsic motivation remains unchanged, this study indicates that gamified implementation improves academic achievement at the university level.
Barba-Martín et al., 2020	200	To examine the scientific research on the application of the TGfU in the educational setting that has been published during the past six years (2014–2019).	Systematic Review	Motor and cognitive learning were the most commonly evaluated in relation to the study's objectives, which centered on enhancing game growth in areas like tactical elements, decision-making, technical proficiency, or degree of physical activity.
Lucena et al., 2019	196	To discuss flipped learning as a cutting-edge method for teaching and learning physical education at the elementary and senior school levels.	Correlational Study	The academic metrics that highlighted the motivation, autonomy, and relationships among the various agents were better evaluated by the experimental group. With respect to the efficacy of flipped learning in relation to educational stage, both stages showed promise, emphasizing a notable increase in secondary school autonomy.
Yu & Jee, 2020	172	To evaluate, in accordance with the ADDIE paradigm, the efficacy of online practical classes (OPC) in physical education (PE) during the COVID-19 pandemic.	Research and Development (RnD)	The results show that for OPC in PE to be successfully implemented, teachers must plan ahead, minimize technical faults, and consistently inspire students. They should also give prompt, high-quality feedback.
Casey & MacPhail, 2018	158	To present the first empirical understanding of teaching physical education through Models-based Practice (MBP) method that incorporates many models.	Experimental Study	Early attempts to employ a multimodel MBP method were constrained by the teacher's capacity to rethink instruction, despite his best efforts. While allowing students to take on a more active role in the classroom, the teacher made "rookie mistakes" and attempted to translate his standard classroom procedures into paper handouts.

Psychological Approach as Learning Methods in Physical Education

Psychology is one of the scientific fields that studies the behavior and psychological condition of a person (Jeong et al., 2022). Psychological science is often used as a medium or tool in studying a person's characteristics. The use of psychology is often related to how a person interacts and communicates with their interlocutors (Moreno-Casado et al., 2023). In PE, the use of psychology is often done by PE teachers in learning the characteristics of students. Psychological science is one way for PE teachers to approach students. The approach is carried out with the aim of understanding how the students are before and during the learning process.

One of the popular approaches is using Self-Determination Theory (SDT) (Sun et al., 2017). SDT is an approach used by PE teachers by providing freedom, fulfilling psychological needs, and determining goals for students (White et al., 2021). The psychological approach through SDT gives students full control over the activities they do, thus making them more confident in doing movement activities in PE learning. In addition, SDT also teaches students to evaluate or reflect on what they have done. In this case, the role of the teacher as a facilitator is important to provide input and direction to students, so that the reflection and evaluation process can be maximized.

The psychological approach using SDT, will make teachers better understand the conditions of their students (Vasconcellos et al., 2020). In addition, students will also have high motivation in participating in PE learning. Thus, the pressure in learning PE can be minimized and students enjoy the learning process more. Through learning methods that pay attention to students' mental health conditions and intrinsic motivation, the learning process will be more enjoyed and felt by students.

Various Learning Methods in Physical Education

In this research, it has been discussed that the learning methods used in physical education learning are very varied. However, in the midst of this diversity, the learning methods that are often used are game-based and group-based, such as cooperative and TGfU (Fernández-Espínola et al., 2020; Nopembri et al., 2022). Cooperative learning method is a learning method that focuses on cooperation between students. The division of students into groups with the aim of solving problems together is done through this learning method. The cooperation will involve social interaction between students, so that the affective domain will also develop indirectly. On the other hand, individual ability is also needed in making appropriate and proportional contributions when the cooperation process is carried out. In this case, good responsibility is needed by each student, so that the learning objectives that have been set can be achieved through cooperative learning methods (Fernández-Río, 2017).

The Teaching Games for Understanding (TGfU) learning method is a learning method that is given to students through various types of innovative and attractive games (Stojanović et al., 2023). These games include ball games, net games, invasion games, and many more. These

terms are pronouns for games in sports by adjusting the type of game. For example, net games are exemplified in TGfU such as badminton, tennis, and volleyball. Then the invasion game, which means attacking the opponent's area, is soccer, basketball, and others. This TGfU learning method is usually applied to students in elementary school, because at that level students recognize PE through games (Papagiannopoulos et al., 2023).

Similar to TGfU, there is a relevant learning method called gamification. The difference is that in this gamification method, the elements in a game (online game) are adapted for PE learning (Gkintoni et al., 2024). The adaptation is such as giving levels, awards, missions, and other things that exist in a game. Leveling can be done by classifying the PE learning process, ranging from easy to difficult. Then, PE teachers will convey related awards obtained by students when successfully completing these levels. This will become a mission or challenge for students in completing the learning process provided.

The learning methods previously described are learning methods that are often used in the PE learning process. Methods with elements of groups and games are considered appropriate to the PE learning process because in PE almost all learning materials are group games. In addition, students' learning motivation can also be encouraged to actively participate in PE learning. This does not mean that other learning methods such as Problem-Based Learning (PBL) or Project-Based Learning (PJBL) cannot be implemented. The implementation of learning methods certainly also takes into account the characteristics of students so that the learning process becomes effective and efficient.

Digitalisation in Physical Education Learning Methods

Based on the systematic review, PE learning process involving digital technology has been happening since 2011 (Casey & Jones, 2011). However, it still has not received attention, because the perception of PE teachers is still oriented towards learning using conventional methods. Digital media-based PE learning methods experienced significant development during the Covid-19 pandemic (Khajornsilp et al., 2021). In order to maintain the PE learning process, various kinds of learning innovations were carried out during the pandemic. In the end, learning methods that initially tended towards games and groups, became learning that was only done in front of the screen. Online learning method or e-learning is rapidly developing in various learning, especially in PE learning (Yu & Jee, 2020).

During the Covid-19 pandemic, learning methods such as PBL and PJBL were implemented in the PE learning process, but the implementation was carried out online (A. K. Hidayat, 2020; Candra et al., 2020). The PBL learning method is in the form of problems presented by the teacher through video analysis or phenomena in the world of sports. Then, students are assigned to provide the right solution either through discussion through critical thinking. While the PJBL learning method, its implementation is almost the same as PBL, but in PJBL students are required to present the assigned project.

The use of technology that has been carried out in recent years has directly stimulated the digitization of learning

methods in PE. Learning methods that initially used conventional media, now experience demands to integrate with digital media. In the end, various learning methods were developed in which digital media were integrated, such as VR (Tang, 2021), AR (Pratama et al., 2022), and other digital media. This is also inseparable from the influence of the digitalization era in the 21st century. All activities in this century cannot be separated from digital influence, so the adaptation of more modern and up-to-date learning methods needs to be done to keep up with the times.

Digitalization that has been carried out in PE learning methods, brings significant changes in the PE learning process. Students who receive the learning process, indirectly recognize digital technologies in PE. The introduction of technology and its implementation in PE has an impact on increasing students' digital literacy. Thus, PE learning is not just a movement activity that involves sports equipment such as kun or mat, but also digital technology.

Pedagogy Skills for Physical Education Teacher

Pedagogical ability is the skill of a teacher in implementing an effective and efficient learning process. The implementation of the learning process, as described in the previous sub-sections, requires proper competence from PE teachers. Competence in providing comfortable learning is needed by PE teachers so that students are able to enjoy the learning process without any pressure in learning (Araújo et al., 2021). PE teachers must also master various learning methods, because in the learning process there will certainly be learning dynamics (Baumgartner, 2022). These dynamics are such as the diversity of student characteristics, environmental or weather conditions, and infrastructure facilities in implementing PE learning. The ability to establish interaction and communication with students well, is needed in order to be able to provide appropriate evaluation and reflection (feedback on the learning process) (Yanova et al., 2021).

Therefore, a PE teacher must have competent pedagogical skills so that the learning process can be maximized (Lohmann et al., 2023). Increasing this competence can be done through a community among PE teachers, as well as training organized by an educational institution. This is important to be able to harmonize with the development of learning methods that have occurred. Good teacher competence will create a good learning environment as well, through the implementation of effective learning methods. Through this, the PE learning process can provide meaningful meaning for students, even when they no longer receive PE learning.

Research Limitations and Future Recommendations

The research has limitations that may be a weakness that needs to be refined in future research. This research only uses four databases, so the number of research documents studied is also limited. Then, the keyword analysis carried out is also only limited to the SCOPUS database, this certainly has an impact on the results of the analysis that is less than optimal. The literature review carried out is also based on the most citations, so there is a possibility that there is literature

that has better research quality, even though the number of citations is small.

In future studies, researchers suggest that the database used for systematic reviews can be expanded. The use of methods or perhaps more efficient software can be integrated in order to obtain more extensive research data. Keyword analysis also needs to be extended to the database so that it does not only focus on SCOPUS. This will allow new findings in the research of learning methods in PE. The researcher also suggested that in future studies to set a year limit, so that the learning methods analyzed are in accordance with current conditions.

These recommendations are given by the researcher so that in future research, research related to learning methods can be developed more broadly. Areas related to technology integration still need to be deepened and explored. Thus, it will be possible for significant developments to occur in PE learning methods that integrate technology, for example learning methods in STEM-based PE.

Conclusions

The development of learning methods in PE has experienced significant dynamics. This development is characterized by its transition from conventional learning methods to modern learning methods. On the other hand, the results of the systematic review also show data that at the beginning of its development, learning methods were still teacher centered and eventually turned into student centered. These developments continue to occur until the learning methods in PE integrate technology during the learning process. This certainly has a positive impact on students and teachers who carry out the teaching and learning process. However, it requires competency development for teachers to be able to implement the development of learning methods effectively and efficiently to students.

The results of the study presented findings that learning methods in PE still focus on the form of games and groups. Although learning methods that have integrated technology have been developed, these methods have not experienced significant development. This research suggests that the development of more modern learning methods can be done, for example, based on STEM. Thus, the learning process will be in accordance with the times and of course also in accordance with the characteristics of today's students.

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Conflict of Interest

The author declares there is no conflict of interest.

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Визначення еволюції методів навчання у галузі фізичного виховання: Систематичний огляд сучасних підходів та цифрової інтеграції

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

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Історія питання. Навчальний процес у галузі фізичного виховання потребує застосування відповідного та ефективного методу навчання. Обов'язком викладачів фізичного виховання є визначення навчальних методик, які б враховували стан здоров'я їхніх учнів.

Мета дослідження. Мета дослідження полягала у проведенні систематичного огляду щодо розвитку методів навчання, які мали місце у фізичному вихованні дотепер.

Матеріали та методи. В якості дослідницьких даних у цій роботі використано чотири наукометричних бази даних: SCOPUS, Google Scholar, OpenAlex та Crossref. Для ідентифікації дослідницьких даних застосовано метод, що відповідає стандарту PRISMA («Переважні елементи звітування для систематичних оглядів та метааналізів»). Крім того, проведено аналіз ключових слів за допомогою програмного забезпечення VosViewer. Також проведено огляд літератури з метою забезпечення більш комплексного розуміння досліджуваних тематик.

Результати. У цьому дослідженні визначено загалом 5358 статей, які були ідентифіковані як систематичні огляди. Результати систематичного огляду показали, що дослідження в галузі фізичного виховання зазнали значного розвитку. До того ж у методах навчання з фізичного виховання також було досягнуто успіху щодо інтеграції цифрових технологій. Такий розвиток характеризується тим, що традиційні методики навчання трансформуються у сучасні навчальні методи. Інтеграція технологій у сучасні методи навчання має позитивний вплив на учнів та викладачів.

Висновки. Отримані дані свідчать про те, що розвиток навчальних методів у галузі фізичного виховання зазнав значних змін. Такі досягнення досі потрібні в аспекті діджиталізації, що забезпечить застосування методів, які більш відповідають потребам майбутнього.

Ключові слова: методи навчання, моделі навчання, педагогіка, учні, викладач.

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