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[Teorià ta Metodika Fìzičnogò Vihovannâ]



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Assessing the Influence of the Flipped Classroom on Physical Education Students' Engagement in Basketball Learning Activities

Cahyo Wibowo^{1ABCDE}, Yahya Eko Nopiyanto^{2BCDE}, Septian Raibowo^{2ACDE}, Bayu Insanistyo^{2ACDE}, Ipa Sari Kardi^{3ACDE}, Ibrahim^{3ACDE}, Rasyono^{4ACDE}, Defliyanto^{4ACDE} and Ansar Cs^{3ACDE}

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Abstract

Background. The flipped classroom approach has been gaining increasing attention across various educational domains, including physical education. Recent research has underscored the necessity for innovative strategies to enhance student engagement in physical education, particularly in basketball instruction.

Objectives. This study aimed to investigate the influence of the flipped classroom approach on student engagement in Basketball instruction within the Physical Education, Health, and Recreation program at the University level.

Materials and methods. The research method involved an experimental design using the static group comparison approach, where 62 students enrolled in physical education were divided into experimental and control groups. The experimental group received instruction through the flipped classroom approach, while the control group underwent conventional instruction, with the intervention lasting for seven weeks. A comprehensive engagement scale questionnaire was used as the research instrument. Data analysis techniques included descriptive analysis and independent samples t-test.

Results. The research findings revealed significantly higher levels of engagement in the agentic, behavioral, emotional, and cognitive dimensions among students in the flipped classroom group compared to those in the conventional classroom group. This indicates that the flipped classroom approach has a considerable effect on student engagement in basketball instruction.

Conclusions. The study's results have confirmed the effectiveness of the innovative pedagogical strategy of the flipped classroom in fostering meaningful learning experiences and motivating students within the context of physical education.

Keywords: flipped, physical education, student engagement, basketball, learning activities.

Introduction

Higher education increasingly emphasizes the importance of active learning involving students' direct participation in learning (Ribeiro-Silva et al., 2022). One field that presents challenges in achieving optimal student

engagement is sports education in physical education programs, where practical experience and direct participation play a crucial role in developing holistic skills. In sports, particularly in basketball education, these challenges become more prominent considering the physical, cognitive, and social aspects that must be considered. Recent research has highlighted the role of technology in changing learning dynamics, with the concept of a "flipped classroom" emerging as an intriguing innovation (McGrath et al., 2017). The flipped classroom reverses the traditional learning approach,

where students are provided with materials beforehand to study independently, utilizing class time for discussions and application of these concepts (Cheng et al., 2019). In the context of sports education, the flipped classroom promises a more interactive and responsive approach to students' needs (Gallardo-Guerrero et al., 2022).

Sports education in higher education settings presents inevitable challenges in creating meaningful learning experiences that can motivate students. In basketball education, aspects such as developing fundamental physical skills, effective gameplay strategies, and teamwork are the focal points. However, there is often a gap between expectations and reality in achieving student engagement in sports learning activities. Recent research has depicted various factors influencing student engagement, including lack of intrinsic motivation, disinterest in the learning subject, and low levels of active participation in the learning process (Li & Xue, 2023; Tani et al., 2021; Xerri et al., 2018).

The basketball course is part of the curriculum of the physical education, health, and recreation program at the university level. Students often encounter significant challenges in understanding gameplay strategies, learning effectiveness, and teaching techniques related to basketball. Based on teaching experience, such issues frequently arise, including students' difficulties in answering questions and demonstrating adequate practical skills. In such situations, a more effective learning approach is required, considering conventional methods such as lectures and demonstrations can pose challenges for students and instructors.

Over the past few decades, academics and educational researchers have questioned the effectiveness of traditional teaching methods such as lectures and demonstrations. Within the realm of physical education and sports, researchers have sought solutions to increasingly pressing challenges. Research findings indicate that using modern approaches and integrating technology into learning can significantly enhance student engagement (Al-Abdullatif & Gameil, 2021; Maseleno et al., 2018). An interactive and participatory classroom environment allows students to explore and acquire relevant and up-to-date information. Therefore, the learning paradigm must emphasize an approach that places students as the primary subjects actively engaged in the learning process.

Learning involving students demands high levels of critical thinking abilities and skills. The principle of constructivism asserts that instructors do not merely impart knowledge to students passively; instead, students must actively construct their knowledge (Amna Saleem et al., 2021; Makewa, 2019). Within an active learning environment, students are encouraged to participate actively in problem-solving, collaborate with peers, share ideas, and provide feedback (Bergström et al., 2023). Therefore, many educators are currently adopting the flipped classroom concept, which integrates pedagogical approaches and modern technology as an alternative to the traditional instructor-centered approach. The flipped classroom approach enables innovative teaching strategies and pedagogies to facilitate active student engagement and address learning challenges (Elmaadaway, 2018; Steen-Utheim & Foldnes, 2018).

While extensive research has been conducted in the context of physical education and sports, several gaps still need to be addressed. Firstly, most studies focus on conventional teaching methods such as lectures and demonstrations.

At the same time, there needs to be more in-depth research on implementing technology and innovative learning approaches, such as the flipped classroom, in physical education, especially in basketball learning. Secondly, there is limited need to specifically explore student engagement in sports education, both in general and considering behavioral, agentic, cognitive, and emotional aspects.

Engagement consists of four distinct yet interconnected aspects: Behavioral, Emotional, Cognitive, and Agentic engagement (O'Donnell et al., 2011; Reeve, 2012). Experts' views vary on student engagement in the classroom, ranging from efforts, consistency, and pro-social behaviors (Behavioral engagement) to high interest and motivation with low levels of anxiety and fatigue (Emotional engagement) to convergence, critical thinking, skilled learning strategies, and self-regulation (Cognitive engagement), as well as deliberate steps taken by institutions to promote individual understanding through learning activities or course materials (Agentic engagement).

Student engagement in the learning process is related to the Self-determination Theory regarding student engagement. The Self-determination Theory posits that intrinsic motivation (motivation originating from within the individual), extrinsic motivation (motivation stemming from external factors), and motivation (lack of motivation) influence individual behavior in achieving goals (Martela, 2020). In the learning context, student engagement in the learning process can be influenced by motivational factors (Uyun et al., 2022). Students who perceive themselves to have control and autonomy in learning (aspects emphasized in the Self-determination Theory) tend to be more actively engaged in the learning process (Huéscar Hernández et al., 2020). Additionally, individuals who feel supported by the learning environment that provides support for basic psychological needs, such as competence, relatedness, and autonomy, also tend to be more engaged in learning (Wang et al., 2019). Thus, the Self-determination Theory perspective can provide a deep understanding of how motivation and learning approaches can be designed to support high motivation and engagement.

This research offers a novel contribution to physical education and sports by bridging existing gaps in the research literature. It expands understanding of the use of instructional technology, particularly the flipped classroom, in sports education, with a specific focus on basketball learning. By integrating this innovative learning approach, the study can potentially enhance student engagement and learning outcomes in the context of sports education. Furthermore, the research underscores the importance of holistically measuring student engagement, encompassing behavioral, agentic, cognitive, and emotional aspects. Thus, the study aims to explore the impact of the flipped classroom approach on student engagement, comprising behavioral, agentic, cognitive, and emotional dimensions, and to assess whether there are differences in the use of classes employing the flipped classroom approach compared to conventional methods (lectures and demonstrations).

Materials and methods

Study participants

The population of this study consists of students enrolled in the physical education, health, and recreation program

at the university level. The research sample comprises students from the physical education, health, and recreation program taking the basketball learning course (invasive game). Sampling was conducted using purposive sampling with 62 students, with 31 students in the experimental group and 31 in the control group. Purposive sampling was chosen because students enrolled in the basketball learning course have direct relevance to the research objectives. The experimental group will receive the flipped classroom treatment, while the control group will undergo learning with the conventional approach (lecture and demonstration).

Study organization

This study employs an experimental approach with the static group comparison design, comprising one experimental group and one control group. This method was chosen to examine the effectiveness of the flipped classroom approach on students' engagement in basketball learning activities. The experimental group will receive the flipped classroom treatment, while the control group will undergo learning with the conventional approach. Comparing these two groups will enable the researchers to evaluate the

impact of implementing the flipped classroom on student engagement.

The research begins with administering treatments to the two groups involved in this study: the experimental group receiving the flipped classroom approach and the control group undergoing learning with the conventional approach. The treatment lasts for seven weeks. The experimental group will receive instruction using the flipped classroom approach, where learning materials are provided in advance for independent study by students through provided resources such as videos, readings, research articles, or other interactive learning materials. Class time is then utilized for discussion, collaboration, and applying the concepts learned beforehand. Summaries can be seen in Tables 1 and 2.

Meanwhile, the control group will learn with a conventional approach, where the lecturer delivers lectures and directly demonstrates the learning material in the classroom/field without prior preparation by the students. After a 7-week treatment, both groups will be given a posttest to measure student engagement based on the agentic, behavioral, emotional, and cognitive aspects. The collected data will be analyzed by calculating the mean of each group, namely the mean of the experimental group receiving the

Table 1. Summary of learning program design for weeks 1-3

Week 1-3				
	Flipped classroom		Conventional Classroom	
	fundamentals of strategy and tactics		fundamentals of strategy and tactics	
	activity	duration	activity	duration
Before class	Man-to-man defense	30'	none	none
	Zone defense	15'		
	Screening	15'		
	Pick and Roll	10'		
	Ball movement	15'		
	Spacing	15'		
	Complex game case studies	30'		
Class activities	Problem-based presentation	50'		
	Problem-solving discussion	50'		
	Evaluation	10'	lectures and demonstrations	

Table 2. Summary of learning program design for weeks 4-7

Week 4-7				
	Flipped classroom		Conventional classroom	
	Practice applying concepts		Practice applying concepts	
	activity	duration	activity	duration
Before class	Video analysis based on case studies	30'	none	none
	Independent practice of several formations in attack and defense	40'		
	Develop the concept of cooperation skills, skills, and decision making	50'		
Class activities	Application of concepts in the field, peer teaching and peer assessment, evaluation	40'	Lectures with lectures and demonstrations by lecturers	
		50'		
		15'		

flipped classroom approach and the mean of the control group undergoing the conventional teaching approach. Comparing these results will provide a deeper understanding of the effectiveness of implementing the flipped classroom in enhancing student engagement in sports education, specifically, in this case, basketball learning.

Research Instrument

The research instrument utilized in this study refers to the adapted Learning Engagement Scale (Reeve & Tseng, 2011). This instrument has been developed and retested for its validity and reliability to suit the research needs and consists of 25 statement items. The first five statements are formulated to assess student behavioral engagement, while the subsequent five questions focus on evaluating student agentic engagement. The following ten questions are designed to evaluate student cognitive engagement, whereas the final five questions aim to assess student emotional engagement. Adaptation of this instrument from a reliable source has been carried out to ensure its suitability and validity within the scope of this research.

Statistical analysis

Data collected in this study were analyzed using descriptive and inferential statistics. Descriptive statistics were employed to present the mean scores of learning engagement across the constructs of agentic, behavioral, emotional, and cognitive engagement. Using descriptive statistics aids in providing a comprehensive overview of the distribution and characteristics of the collected data. Furthermore, to determine whether there were differences in the mean scores of engagement between flipped classrooms and conventional classes, an Independent Samples t-test was utilized. This test allows for the statistically significant comparison of means or averages between two different sample groups. The results of this test will provide a deeper understanding of the effectiveness of each teaching approach in influencing the level of student engagement. The SPSS 22 application package was used to process the data.

Results

This study adopts a comprehensive approach to address key research questions regarding the influence of the flipped classroom approach on student engagement across four key dimensions: agentic, behavioral, emotional, and cognitive. With careful and objective analysis, a comparison is made between the flipped classroom approach and conventional methods such as lectures and demonstrations. This research's findings significantly contribute to enriching understanding of the effectiveness of this instructional approach in enhancing student engagement.

Table 3 indicates that the average scores for each statement regarding the agentic aspect range from 2.94 to 3.45. The highest score is obtained for statement A1, indicating that students actively ask questions during the learning process, with an average score of 3.45. This suggests that the flipped classroom approach encourages students to participate more proactively and interact during the learning sessions. On the other hand, statement A4 has the lowest average

score of 2.94, indicating that students are slightly less active in voicing their preferences and views during basketball learning. Nevertheless, overall, the results indicate that the flipped classroom approach positively impacts the agentic aspect of students in the context of basketball learning.

Table 3. The mean aspect of agentic engagement

Description	Mean
A1. During the learning sessions, I actively engage in asking questions.	3.45
A2. I communicate my preferences to the instructor, including things I like and dislike	3.23
A3. I communicate my interests to the instructor.	3.10
A4. During the basketball learning session, I voice my preferences and opinions.	2.94
A5. I provide feedback to improve the quality of basketball learning.	3.06

Table 4 shows the average scores for each statement regarding the behavioral aspect, ranging from 3.03 to 3.32. The most prominent behavior is "When the instructor begins discussing a new topic, I carefully listen to the explanation," with an average score of 3.32. This indicates that the flipped classroom approach can encourage students to follow the presented material actively, demonstrating a high level of precision in understanding new topics. On the other hand, the statement "I am very dedicated when starting something new in the learning process in class" obtained the lowest score, which is 3.03. This suggests that there is still potential to improve students' dedication levels when facing new challenges in learning. Overall, these results indicate that the flipped classroom approach positively impacts students' behavior, enhancing their precision and engagement in the basketball learning process.

Table 4. The mean aspect of behavioral engagement

Description	Mean
B1. I actively listen attentively during the learning process	3.13
B2. I make a sincere effort to complete tasks in the campus environment	3.16
B3. When the instructor begins discussing a new topic, I carefully listen to the explanation	3.32
B4. I am very dedicated when starting something new in the learning process in class	3.03
B5. I always pay close attention during the basketball learning process	3.16

The table 5 shows the average scores for each statement regarding the emotional aspect, ranging from 3.19 to 3.68. The most prominent statement is "When engaged in basketball learning activities, I feel interested and actively involved in the tasks or discussions provided," with an average score of 3.68. This indicates that the flipped classroom approach can create an engaging learning atmosphere and spark students' interest in learning activities. Additionally, the statement "Basketball learning class is delightful and inspiring" also received a high score of 3.61, indicating that students

perceive the learning experience positively and motivating. However, "I feel enthusiastic and excited when introduced to new concepts or materials in basketball learning" obtained the lowest score of 3.19, indicating that there is still room to improve students' enthusiasm and excitement. These results suggest that the flipped classroom approach positively impacts students' emotional aspects, creating a fun, inspiring learning environment and arousing interest and enthusiasm in basketball learning.

Table 5. The mean aspect of emotional engagement

Description	Mean
E1. I feel enthusiastic and excited when introduced to new concepts or materials in basketball learning	3.19
E2. I am interested and actively involved in the tasks or discussions provided when engaged in basketball learning activities	3.68
E3. While in class, I feel curious and eager to know more about the topics or materials being learned, so I often seek additional information	3.29
E4. I enjoy the atmosphere created in the class	3.35
E5. The basketball learning class is delightful and inspiring	3.61

Table 6 displays the average scores for each statement regarding the cognitive aspect, ranging from 2.99 to 3.81. Special attention is given to the statement, "I strive to organize all different ideas into a logical whole when I am studying, making it easier for me to understand the material thoroughly," which obtained the highest average score of 3.81. This indicates that the flipped classroom approach encourages students to develop the ability to integrate various concepts and information to gain a comprehensive understanding. However, the statement "To aid my understanding of important concepts, I often create my relevant examples from everyday life" received the lowest average score of 2.99, indicating that there is still room to improve the implementation of learning strategies more relevant to daily life. These results demonstrate that the flipped classroom approach positively impacts students' cognitive aspects by encouraging them to connect new concepts with previous knowledge, use personal experiences to enrich understanding, and develop the ability to organize ideas logically.

The data analysis results in Table 7 reveal a comparison of student engagement across agentic, behavioral, emotional, and cognitive aspects between two learning groups, namely

Table 6. The mean aspect of cognitive engagement

Description	Mean
C1. When completing coursework assignments, I endeavor to connect new concepts I have learned with the knowledge I already possess	3.45
C2. Throughout the learning process, I strive to link my study material with my personal experiences to enrich my understanding	3.48
C3. I organize all different ideas into a logical whole when I am studying, making it easier for me to understand the material thoroughly	3.81
C4. I often create relevant examples from everyday life to aid my understanding of important concepts	2.99
C5. Before I begin studying, I create a plan and consider the goals I want to achieve to focus and be efficient in the learning process	3.58
C6. When working on assignments, I regularly evaluate my progress by pausing and reviewing my previous accomplishments	3.42
C7. Throughout the learning process, I always assess the extent of my understanding of the material, not just focusing on the correctness of the answers I obtain	3.03
C8. If I struggle to understand the material, I try various learning approaches or strategies to enhance my comprehension.	3.42
C9. I actively seek additional reference sources to support my understanding of the material being studied.	3.53
C10. When facing challenges in comprehension, I am quick to ask classmates for assistance or seek help from the instructor to clarify concepts I need help understanding.	3.42

flipped classroom and conventional. Regarding the agentic aspect, the mean student engagement in the flipped classroom group ($M = 3.15$, $SD = 0.34$) surpasses that of the conventional group ($M = 2.94$, $SD = 0.24$). Similarly, concerning the behavioral aspect, student engagement within the flipped classroom group ($M = 3.18$, $SD = 0.16$) exhibits a higher figure than the conventional group ($M = 3.08$, $SD = 0.17$). Furthermore, in the emotional aspect, students in the flipped classroom group ($M = 3.42$, $SD = 0.27$) also demonstrate a higher engagement level than the conventional group ($M = 3.04$, $SD = 0.25$). Lastly, in

Table 7. Group Statistic

Item	Grup	N	Mean	SD	Levene's test	t	Sig (2 tailed)
Agentic	Flipped classroom	31	3.15	0.34	0.076	2.786	0.007
	Conventional classroom	31	2.94	0.24			
Behavioral	Flipped Classroom	31	3.18	0.16	0.554	2.218	0.03
	Conventional Classroom	31	3.08	0.17			
Emotional	Flipped Classroom	31	3.42	0.27	0.468	5.667	0.000
	Conventional Classroom	31	3.04	0.25			
Cognitive	Flipped Classroom	31	3.39	0.23	0.064	3.864	0.000
	Conventional Classroom	31	3.19	0.15			

the cognitive aspect, student engagement within the flipped classroom group ($M = 3.39$, $SD = 0.23$) also outperforms that of the conventional group ($M = 3.19$, $SD = 0.15$). From these findings, the flipped classroom approach positively contributes to student engagement across various learning aspects, encompassing agentic, behavioral, emotional, and cognitive dimensions.

Levene's test results indicate that for the agentic aspect, Levene's test value is 0.076, with a t -value of 2.786 and a two-tailed significance value (Sig) of 0.007. This suggests that the data variance between the flipped classroom and conventional groups is homogeneous. Conversely, Levene's test value is 0.554 for the behavioral aspect, with a t -value of 2.218 and a two-tailed Sig of 0.03. These results show a significant difference in the mean behavioral engagement between the two groups. Furthermore, in the emotional aspect, Levene's test value is 0.468 with a t -value of 5.667 and a two-tailed Sig of 0.000. These findings indicate a significant difference between the flipped classroom and conventional groups regarding emotional engagement. Lastly, Levene's test value is 0.064 for the cognitive aspect, with a t -value of 3.864 and a two-tailed Sig of 0.000. This confirms a significant difference between the two groups in cognitive engagement. Thus, these findings provide evidence that the flipped classroom approach significantly impacts student engagement in agentic, behavioral, emotional, and cognitive aspects compared to the conventional classroom approach.

Discussion

The research analysis reveals significant findings regarding the influence of the flipped classroom approach on student engagement across various aspects of learning involvement. In the agentic aspect, students undergoing instruction via the flipped classroom approach exhibit a higher engagement level than those following conventional methods. This is evident from higher average scores on statements indicating proactive activities during participation and interaction throughout the learning sessions. These results align with previous literature emphasizing the importance of active participation in enhancing learning outcomes (González et al., 2021). Students actively engaged in classroom discussions and collaborative projects tend to achieve higher levels of understanding and academic outcomes compared to those merely acting as passive listeners in the learning process (González et al., 2021). Mahasiswa yang secara aktif terlibat dalam diskusi kelas dan proyek kolaboratif cenderung mencapai tingkat pemahaman yang lebih tinggi dan hasil akademis yang lebih baik daripada mereka yang hanya menjadi pendengar pasif dalam proses pembelajaran (Amerstorfer & Frein von Münster-Kistner, 2021; Cavinato et al., 2021; Digout & Samra, 2023). Thus, this research underscores the significance of active participation in enhancing student learning outcomes.

In the behavioral aspect, students within the flipped classroom group also demonstrate a higher level of engagement, particularly in comprehending new material and exhibiting dedication in facing learning challenges. This indicates that the flipped classroom approach can stimulate more proactive and goal-oriented behaviors in learning. This is consistent with constructivist learning theory, which emphasizes the importance of student-centered learning and

active methods in the learning process (Efgivia et al., 2021). Using the flipped classroom approach in university settings has the potential to develop various aspects of student behavior (Han, 2022). In this context, students can prepare themselves beforehand with the provided materials before class meetings. This aids them in feeling more prepared and confident when participating in class discussions. Additionally, the flipped classroom approach encourages active learning, wherein students are more directly involved in the learning process through discussions, problem-solving, and collaboration with fellow students. Through this increased level of interaction, students can develop communication skills, cooperation, and problem-solving abilities, all of which are crucial aspects of the behavioral development of students in university environments (Salleh, 2022a).

The utilization of the flipped classroom holds the potential to enrich various aspects of student behavior within university environments. By fostering active engagement in high-level tasks, this approach stimulates students' involvement in complex problem-solving, in-depth analysis, and synthesis of information necessary to achieve profound understanding. Furthermore, the flipped classroom can influence students' perceptions of learning by considering individual characteristics, learning preferences, and interactions within the learning environment (Salleh, 2022b). These factors can affect enjoyment, boredom, and perceived self-efficacy in facing academic tasks. By acknowledging and adapting learning experiences to meet the needs and preferences of individual students, the flipped classroom can serve as an effective tool for developing diverse student behaviors at the university level (Cho et al., 2021).

The results indicate that the flipped classroom approach positively impacts students' emotions. They feel more interested, motivated, and enthusiastic about participating in learning activities. This suggests that the flipped classroom approach's more interactive and responsive learning atmosphere can enhance students' emotional engagement. Consistent with research findings, the flipped classroom approach shows a positive correlation with increased confidence, motivation, and student engagement in the learning process (Hu et al., 2022; Xiu & Thompson, 2020; Zarouk et al., 2020). They allow students to have access to learning materials before class sessions and allow them to feel more confident in understanding the concepts taught. Thus, the flipped classroom approach correlates with increased comprehension of the material and enhancements in psychological and motivational factors crucial for academic success (Awidi & Paynter, 2019).

In the cognitive aspect, students engaged in the flipped classroom group demonstrate higher involvement. They tend to comprehend the material comprehensively, connect new concepts with previous knowledge, and utilize personal experiences to enrich their understanding. These findings align with research indicating that the flipped classroom approach can stimulate critical and reflective thinking among students in the learning process (Moon, 2023; Orhan, 2023). By encouraging students to engage in deeper thinking about the material, connect the taught concepts with existing knowledge, and relate them to personal experiences, this approach aids in developing higher-order thinking skills and a deeper understanding of the learning material. This reflects

the positive contribution of the flipped classroom approach to the cognitive development of students in challenging and student-centered learning contexts.

The implications of these findings suggest that the flipped classroom approach can be considered an effective alternative for enhancing student engagement in the learning process. Practical implications include educational practitioners adopting this approach to create more meaningful and interactive learning experiences. Additionally, these findings contribute theoretically to expanding understanding of the effectiveness of various teaching methods in improving student learning outcomes.

It is important to remember that this research has limitations that should be acknowledged. Using a limited sample may restrict the generalization of the research findings to a broader population. With relatively small participant numbers in each group, the possibility of significant individual variations in response to specific teaching approaches may need to be fully reflected. Furthermore, specific learning environments, such as basketball learning, may also limit the generalizability of these findings to other learning contexts. Using research instruments that may be partially valid or reliable could affect the accuracy of measuring student engagement. Although adapted from reliable instruments, there is a possibility that the questions in the learning engagement scale need to reflect the intended constructs entirely accurately. Moreover, the subjective nature of students' self-assessment of their engagement may also influence the results.

Furthermore, the research design used has limitations. Although a comparison has been made between two groups, namely the flipped classroom and conventional approaches, there needs to be precise control over variables that may influence student engagement apart from the implemented teaching approach. This could result in uncontrolled confounding variables affecting the research outcomes. The limited research time can also be a constraint. Not all aspects of student engagement may be thoroughly explored within a limited time.

Conclusions

In conclusion, this research demonstrates that the flipped classroom approach significantly impacts student engagement across various learning aspects, including agentic, behavioral, emotional, and cognitive dimensions. These findings indicate that the flipped classroom approach stimulates more proactive and goal-oriented engagement in learning, enhances comprehensive understanding of the material, and encourages the utilization of higher-order cognitive skills by students. Students actively involved in learning, whether through interaction with instructors or peers, tend to achieve better learning outcomes. Therefore, approaches emphasizing active participation, such as the flipped classroom, can be considered effective alternatives for enhancing learning outcomes.

The flipped classroom approach offers significant potential for improving student engagement and learning outcomes. However, adjustments need to be made to implement it effectively according to specific learning needs and contexts. Thus, further research and exploration of this approach would be valuable steps in developing more effective and inclusive sports education in the future.

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Conflict of interest

The authors declare there is no conflict of interest.

References

- Ribeiro-Silva, E., Amorim, C., Aparicio-Herguedas, J. L., & Batista, P. (2022). Trends of Active Learning in Higher Education and Students' Well-Being: A Literature Review. *Frontiers in Psychology*, 13. <https://doi.org/10.3389/fpsyg.2022.844236>
- McGrath, D., Groessler, A., Fink, E., Reidsema, C., & Kavanagh, L. (2017). *Technology in the Flipped Classroom*. In *The Flipped Classroom* (pp. 37–56). Springer Singapore. https://doi.org/10.1007/978-981-10-3413-8_3
- Cheng, L., Ritzhaupt, A. D., & Antonenko, P. (2019). Effects of the flipped classroom instructional strategy on students' learning outcomes: a meta-analysis. *Educational Technology Research and Development*, 67(4), 793–824. <https://doi.org/10.1007/s11423-018-9633-7>
- Gallardo-Guerrero, A.-M., Maciá-Andreu, M.-J., Conde-Pascual, E., Sánchez-Sáez, J.-A., Zurita-Ortiz, B., & García-Tascón, M. (2022). From Flipped Classroom to Personalised Learning as an Innovative Teaching Methodology in the Area of Sports Management in Physical Activity and Sport Sciences. *Sustainability*, 14(13), 7714. <https://doi.org/10.3390/su14137714>
- Li, J., & Xue, E. (2023). Dynamic Interaction between Student Learning Behaviour and Learning Environment: Meta-Analysis of Student Engagement and Its Influencing Factors. *Behavioral Sciences*, 13(1), 59. <https://doi.org/10.3390/bs13010059>
- Tani, M., Gheith, M. H., & Papaluca, O. (2021). Drivers of student engagement in higher education: a behavioral reasoning theory perspective. *Higher Education*, 82(3), 499–518. <https://doi.org/10.1007/s10734-020-00647-7>
- Xerri, M. J., Radford, K., & Shacklock, K. (2018). Student engagement in academic activities: a social support perspective. *Higher Education*, 75(4), 589–605. <https://doi.org/10.1007/s10734-017-0162-9>
- Al-Abdullatif, A. M., & Gameil, A. A. (2021). The Effect of Digital Technology Integration on Students' Academic Performance through Project-Based Learning in an E-learning Environment. *International Journal of Emerging Technologies in Learning (IJET)*, 16(11), 189. <https://doi.org/10.3991/ijet.v16i11.19421>
- Maseleno, A., Huda, M., Mat Teh, K. S., Don, A. G., Basiron, B., Jasmi, K. A., Mustari, M. I., Nasir, B. M., & Ahmad, R. (2018). Understanding Modern Learning Environment (MLE) in Big Data Era. *International Journal of Emerging Technologies in Learning (IJET)*, 13(05), 71. <https://doi.org/10.3991/ijet.v13i05.8042>
- Amna Saleem, Huma Kausar, & Farah Deebea. (2021). Social Constructivism: A New Paradigm in Teaching and

- Learning Environment. *Perennial Journal of History*, 2(2), 403-421. <https://doi.org/10.52700/pjh.v2i2.86>
- Makewa, L. N. (2019). *Constructivism Theory in Technology-Based Learning* (pp. 268-287). <https://doi.org/10.4018/978-1-5225-5915-3.ch015>
- Bergström, P., Rönnlund, M., & Tieva, Å. (2023). *Making the Transition from Teacher-Centered Teaching to Students' Active Learning: Developing Transformative Agency*. In *Creating Dynamic Places for Learning* (pp. 99-115). Springer Nature Singapore. https://doi.org/10.1007/978-981-19-8749-6_6
- Elmaadaway, M. A. N. (2018). The effects of a flipped classroom approach on class engagement and skill performance in a Blackboard course. *British Journal of Educational Technology*, 49(3), 479-491. <https://doi.org/10.1111/bjet.12553>
- Steen-Utheim, A. T., & Foldnes, N. (2018). A qualitative investigation of student engagement in a flipped classroom. *Teaching in Higher Education*, 23(3), 307-324. <https://doi.org/10.1080/13562517.2017.1379481>
- O'Donnell, M. A., Reeve, J., & Smith, K. J. (2011). *Educational psychology: Reflection for action* (Third Edition). Jhon Wiley & Sons.
- Reeve, J. (2012). *A Self-determination Theory Perspective on Student Engagement*. In *Handbook of Research on Student Engagement* (pp. 149-172). Springer US. https://doi.org/10.1007/978-1-4614-2018-7_7
- Martela, F. (2020). *Self-Determination Theory*. In *The Wiley Encyclopedia of Personality and Individual Differences* (pp. 369-373). Wiley. <https://doi.org/10.1002/9781118970843.ch61>
- Uyun, M., Bahriah, Y., & Fitriani, F. (2022). Interest and learning motivation with student participation. *Psikoislamedia: Jurnal Psikologi*, 7(2). <https://doi.org/10.22373/psikoislamedia.v7i2.13794>
- Hués-car Hernández, E., Andrés Fabra, J. A., & Moreno-Murcia, J. A. (2020). Effect of autonomy support and dialogic learning on school children's physical activity and sport. *Scandinavian Journal of Psychology*, 61(3), 402-409. <https://doi.org/10.1111/sjop.12637>
- Wang, Y., Tian, L., & Scott Huebner, E. (2019). Basic psychological needs satisfaction at school, behavioral school engagement, and academic achievement: Longitudinal reciprocal relations among elementary school students. *Contemporary Educational Psychology*, 56, 130-139. <https://doi.org/10.1016/j.cedpsych.2019.01.003>
- Reeve, J., & Tseng, C.-M. (2011). Agency as a fourth aspect of students' engagement during learning activities. *Contemporary Educational Psychology*, 36(4), 257-267. <https://doi.org/10.1016/j.cedpsych.2011.05.002>
- González, C., Varela, J., Sánchez, P. A., Venegas, F., & De Tezanos-Pinto, P. (2021). Students' Participation in School and its Relationship with Antisocial Behavior, Academic Performance and Adolescent Well-Being. *Child Indicators Research*, 14(1), 269-282. <https://doi.org/10.1007/s12187-020-09761-5>
- Amerstorfer, C. M., & Frein von Münster-Kistner, C. (2021). Student Perceptions of Academic Engagement and Student-Teacher Relationships in Problem-Based Learning. *Frontiers in Psychology*, 12. <https://doi.org/10.3389/fpsyg.2021.713057>
- Cavinato, A. G., Hunter, R. A., Ott, L. S., & Robinson, J. K. (2021). Promoting student interaction, engagement, and success in an online environment. *Analytical and Bioanalytical Chemistry*, 413(6), 1513-1520. <https://doi.org/10.1007/s00216-021-03178-x>
- Digout, J., & Samra, H. El. (2023). *Interactivity and Engagement Tactics and Tools*. In *Governance in Higher Education* (pp. 151-169). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-40586-0_8
- Efgivia, M. G., Adora Rinanda, R. Y., Suriyani, Hidayat, A., Maulana, I., & Budiarjo, A. (2021). Analysis of Constructivism Learning Theory: 1st UMGESHIC International Seminar on Health, Social Science and Humanities (UMGESHC-ISHSSH 2020), Gresik, Indonesia. <https://doi.org/10.2991/assehr.k.211020.032>
- Han, S. (2022). Flipped classroom: Challenges and benefits of using social media in English language teaching and learning. *Frontiers in Psychology*, 13. <https://doi.org/10.3389/fpsyg.2022.996294>
- Salleh, S. M. (2022a). University Student Perceptions on the Use of Online-Based Technology in Flipped Classrooms. *International Journal of Computer-Assisted Language Learning and Teaching*, 12(4), 1-15. <https://doi.org/10.4018/IJCALLT.310078>
- Salleh, S. M. (2022b). University Student Perceptions on the Use of Online-Based Technology in Flipped Classrooms. *International Journal of Computer-Assisted Language Learning and Teaching*, 12(4), 1-15. <https://doi.org/10.4018/IJCALLT.310078>
- Cho, M.-H., Park, S. W., & Lee, S. (2021). Student characteristics and learning and teaching factors predicting affective and motivational outcomes in flipped college classrooms. *Studies in Higher Education*, 46(3), 509-522. <https://doi.org/10.1080/03075079.2019.1643303>
- Hu, T., Zhang, M., Liu, H., Liu, J., Pan, S., Guo, J., Tian, Z., & Cui, L. (2022). The influence of "small private online course + flipped classroom" teaching on physical education students' learning motivation from the perspective of self-determination theory. *Frontiers in Psychology*, 13. <https://doi.org/10.3389/fpsyg.2022.938426>
- Xiu, Y., & Thompson, P. (2020). Flipped University Class: A Study of Motivation and Learning. *Journal of Information Technology Education: Research*, 19, 041-063. <https://doi.org/10.28945/4500>
- Zarouk, M. Y., Olivera, E., Peres, P., & Khaldi, M. (2020). The Impact of Flipped Project-Based Learning on Self-Regulation in Higher Education. *International Journal of Emerging Technologies in Learning (IJET)*, 15(17), 127. <https://doi.org/10.3991/ijet.v15i17.14135>
- Awidi, I. T., & Paynter, M. (2019). The impact of a flipped classroom approach on student learning experience. *Computers & Education*, 128, 269-283. <https://doi.org/10.1016/j.compedu.2018.09.013>
- Moon, S. J. (2023). The Effect of Flipped Learning on Critical Thinking Ability, Communication Ability, and Problem Solving Ability of Nursing College Students. *Korean Association For Learner-Centered Curriculum And Instruction*, 23(1), 157-167. <https://doi.org/10.22251/jlcci.2023.23.1.157>
- Orhan, A. (2023). Comparing the Effectiveness of Online, Flipped, and In-Class Critical Thinking Instruction on Critical Thinking Skills and Dispositions in Higher Education: Flipped Classroom Produces the Greatest Gains. *International Journal of Technology in Education*, 6(2), 238-259. <https://doi.org/10.46328/ijte.376>

Оцінка впливу застосування методу «перевернутого класу» на залученість студентів з фізичного виховання до навчальної діяльності з баскетболу

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Історія питання. Метод навчання за принципом «перевернутого класу» привертає дедалі більше уваги в різних освітніх галузях, зокрема й у фізичному вихованні. Нещодавні дослідження підкреслюють необхідність впровадження інноваційних стратегій щодо підвищення залученості студентів до фізичного виховання, зокрема, до навчання баскетболу.

Мета дослідження. Метою цього дослідження було вивчення впливу застосування методу «перевернутого класу» на рівень залученості студентів до занять баскетболом в рамках програми «Фізичне виховання, здоров'я та рекреація» на університетському рівні.

Матеріали та методи. Дослідницький метод передбачав проведення експерименту з використанням підходу статичного групового порівняльного аналізу, у якому 62 студенти, які навчаються на факультеті фізичного виховання, були розділені на експериментальну та контрольну групи. Експериментальна група проходила навчання за технологією «перевернутого класу», тоді як контрольна група навчалася за традиційною методикою із проведенням інтервенції впродовж семи тижнів. В якості інструменту дослідження використовувався комплексний опитувальник за шкалою залученості. Методи аналізу даних включали описовий аналіз та t-критерій незалежних вибірок.

Результати. Результати дослідження показали значно вищі показники залученості в діяльнісному, поведінковому, емоційному та когнітивному вимірах серед студентів у групі із застосуванням моделі «перевернутого класу» порівняно з групою зі звичайною методикою навчання. Це свідчить про суттєвий вплив методу «перевернутого класу» на рівень залученості студентів до навчання баскетболу.

Висновки. Результати дослідження підтверджують ефективність впровадження інноваційної педагогічної стратегії «перевернутого класу» у стимулюванні процесу осмисленого навчання та мотивації студентів у контексті фізичного виховання.

Ключові слова: перевернутий, фізичне виховання, залученість студентів, баскетбол, навчальні заходи.

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Physical Education by Improving Students' Interpersonal Communication Skills

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Abstract

Background. Interpersonal communication skills have a significant influence that must be emphasized on the implementation of learning at school. Consequently, ongoing evaluation of students is essential to achieve optimal interpersonal communication skills.

Objectives. This study aimed to examine the impact of implementing physical education on interpersonal communication skills in Senior High School (SMA) and Vocational School (SMK) students. Both types of schools have distinctive characteristics. Senior High School focuses more on continuing education, while Vocational School places greater emphasis on education that prioritizes the readiness of its graduates to work.

Materials and methods. Quantitative descriptive approach is employed in this study, with high school and vocational school students as the research sample. The Interpersonal Communication Competence Scale (ICCS) is the research tool used in this study.

Results. Based on the research findings, it is clear that there are differences in the results of interpersonal communication skills between high school and vocational school students compared to the outcomes of implementing physical education at school. This is evidenced by the results of the independent sample t-test (two-sided p-value) < 0.001. Furthermore, it can also be observed that based on gender (male and female), it is obtained 0.002. Both results have a significance level of < 0.05.

Conclusions. The findings indicate that vocational school students' interpersonal communication skills have been found to be improved than high school students.

Keywords: physical education, interpersonal communication, school, student, vocational school, senior high school.

Introduction

Interpersonal communication skills are crucial for students in physical education classes (Hacıcaferoğlu, 2022; Mas'amah et al., 2023; Stoddart & Humbert, 2021). Through effective communication, students can collaborate with their peers, engage in team sports, and understand the importance of clear instructions and feedback from their teachers (Hawani et al., 2020; Laufs & Waseem, 2020). In addition, interpersonal communication skills can also help students in resolving conflicts, expressing their ideas, and

building a supportive and inclusive environment within the physical education setting (Hacıcaferoğlu, 2022; Lamb et al., 2016; Laufs & Waseem, 2020). By honing these skills, students can not only improve their performance in sports and physical activities but also develop important life skills that will benefit them in their personal and professional lives.

It is important for physical education teachers to actively foster and encourage the development of interpersonal communication skills among their students. Teachers can incorporate group activities, partner exercises, and team sports that require effective communication and cooperation (Chermak & Weiss, 2005). Furthermore, providing opportunities for students to practice giving and receiving constructive feedback can greatly enhance their interpersonal communication abilities. In addition to in-class activities,

integrating communication skill-building exercises into the curriculum can be beneficial (Nichols et al., 2014; Sun, 2011). These exercises can include role-playing scenarios, group discussions, and communication workshops. By consistently reinforcing the importance of interpersonal communication, students will be better equipped to navigate social interactions, work collaboratively, and lead successful, active lives beyond the school setting (Chermak & Weiss, 2005).

As educators continue to prioritize the development of interpersonal communication skills in physical education, students will be well-prepared to engage in healthy, productive relationships, both on and off the field (Hacıcaferoğlu, 2022; Park et al., 2021; Sutherland & Parker, 2020). Physical education classes provide an ideal environment for students to not only improve their physical fitness but also to enhance their interpersonal communication skills (Primo et al., 2023; Sutherland & Parker, 2020; White et al., 2023). With the guidance of supportive teachers, students can learn to effectively communicate, collaborate, and resolve conflicts, which are all essential skills for success both inside and outside of the classroom (Amadi & Kufre Paul, 2017; Kourkouta & Papathanasiou, 2014). As students develop these capabilities, they not only improve their performance in sports and physical activities but also lay the foundation for successful personal and professional relationships in the future.

In addition to the various activities and exercises mentioned, it is crucial for physical education teachers to serve as role models for effective communication (Guan, 2023; White et al., 2023). By demonstrating active listening, clear expression, and empathy, teachers can instill valuable communication habits in their students (Hawani et al., 2020; Stoddart & Humbert, 2021). Moreover, integrating technology and multimedia resources into the curriculum can provide additional opportunities for students to enhance their communication skills, such as creating and delivering presentations or utilizing digital tools for collaborative projects (Bhat, 2023; Ganan et al., 2014; Zin et al., 2013).

By fostering a positive and inclusive environment in physical education classes that prioritizes communication and teamwork, educators can empower students to become confident and effective communicators both on and off the field (Lamb et al., 2016; Stoddart & Humbert, 2021; Yang et al., 2021). This emphasis on interpersonal communication skills can ultimately contribute to the holistic development of students and prepare them for success in their future endeavors. As students continue to hone their interpersonal communication skills in physical education classes, they also have the opportunity to apply these skills beyond the school environment (Dina & Dina, 2014; Lamb et al., 2016; Widyaningsih et al., 2020). For example, when participating in community sports or recreational activities, students can utilize their enhanced communication abilities to work effectively as part of a team and to express their thoughts and ideas with confidence (Altun et al., 2018; Bailey, 2006; Sullivan, 1993).

Moreover, the benefits of strong interpersonal communication skills extend into the professional realm. In future careers, individuals who possess adept communication skills are often more successful in collaborating with colleagues, clients, and stakeholders (Hulbert et al., 1987; Jiang, 2018; Lolli, 2013). By emphasizing the importance of these skills in physical education, educators are not only nurturing students' physical abilities but also equipping

them with the essential tools for thriving in various aspects of their lives (Dyson, 2014; Madrona et al., 2019; Stoddart & Humbert, 2021).

As students advance through their education, the development of these interpersonal communication skills will continue to serve as a valuable asset, promoting success in their academic pursuits and beyond (Amadi & Kufre Paul, 2017; Iksan et al., 2012; Martín, 2014a; Wayne et al., 1992). Teachers play a pivotal role in this journey, as they encourage and guide students in harnessing their communication skills to become well-rounded individuals who are prepared to face the challenges of the future. With a strong foundation in interpersonal communication, students are poised to navigate the complexities of relationships and teamwork with confidence and proficiency.

In addition to the strategies mentioned, integrating peer feedback exercises into the physical education curriculum can further enhance students' interpersonal communication skills (Double et al., 2020). Peer feedback provides students with the opportunity to not only receive input from their classmates but also to practice giving constructive criticism in a supportive manner (El-Sherif, 2014; Shin et al., 2007). Through this process, students develop empathy, active listening, and the ability to effectively articulate their thoughts. By incorporating structured peer feedback sessions into activities and team sports, students can gain valuable insights into their own communication styles and learn to adapt their approach based on their peers' feedback (Mills et al., 2014; Nichols et al., 2014). This fosters a deeper understanding of the importance of clear and respectful communication, which can have a positive impact on their interactions both on and off the field.

Encouraging students to reflect on and discuss the feedback they receive from their peers can also promote self-awareness and personal growth (Hacıcaferoğlu, 2022). As they become more attuned to their own communication strengths and areas for improvement, students can take proactive steps to refine their skills and become more effective communicators (Hodder et al., 1989; Nofziger et al., 2010; Simonsmeier et al., 2020). Moreover, integrating peer feedback into physical education classes aligns with the broader goal of cultivating a culture of support and collaboration. Students learn to value the perspectives of their peers and recognize the collective benefit of effective communication within a team or group setting (Martineau et al., 2016; Zhou et al., 2021). This emphasis on mutual respect and understanding contributes to the creation of a positive and inclusive environment, reinforcing the importance of communication as a foundational element of successful interpersonal relationships.

By actively incorporating peer feedback initiatives, physical education teachers can empower students to actively engage in the continuous improvement of their communication skills, thereby preparing them for the multifaceted demands of their future personal and professional endeavors.

Materials and methods

Participants

This research involved 394 high school and vocational school students (155 high school students and 239 vocational school students), then based on gender there were

183 men and 211 women. Furthermore, this research looks at interpersonal communication skills resulting from the implementation of physical education in schools. According to Regulation of The Minister of Education and Culture of The Republic of Indonesia, Number 34 of 2018 Concerning, National Standards for Vocational Secondary School Education/Vocational Madrasah Aliyah (Kemendikbud, 2018), the two schools have different learning objectives. The goals of high school education focus on general education which prepares students to continue their education to a higher level (university or college). The curriculum covers a variety of academic subjects such as mathematics, natural sciences, social sciences, and languages. Meanwhile, SMK focuses on vocational education which prepares students to immediately enter the world of work after graduating. The curriculum focuses more on practical and technical skills in certain fields such as engineering, business, tourism, health, and others.

Based on these differences, it will be possible to produce results that will look at students' interpersonal communication skills and the impact of physical education learning at school. Apart from that, it will explicitly know based on gender.

Instrument

The Interpersonal Communication Competence Scale (Rubin & Martin, 1994) is a widely used tool to measure the effectiveness of physical education programs in improving students' interpersonal communication skills. The scale provides valuable insights into the impact of physical education on students' ability to communicate effectively in various social and professional contexts. Research utilizing the ICCS has shown that comprehensive physical education programs not only contribute to students' physical well-being but also play a crucial role in fostering essential interpersonal communication skills. By integrating the ICCS into the assessment of physical education initiatives, educators and policymakers can gain a deeper understanding of the specific areas of interpersonal communication where students excel and where they may need additional support.

Furthermore, the utilization of the ICCS allows for the continuous evaluation and improvement of physical education programs to better align with the evolving needs of students in today's interconnected world. As educational institutions continue to prioritize the development of students' interpersonal communication skills, the ICCS serves as a valuable tool for ensuring that physical education remains an integral component of the broader educational curriculum. Incorporating the ICCS into the ongoing assessment of physical education programs will provide valuable data to support the further exploration and refinement of these initiatives. Through the conscientious use of the ICCS, educational institutions can continue to adapt and enhance their approach to physical education, ensuring that students are equipped with the necessary interpersonal communication skills to succeed in a complex and rapidly changing global landscape.

Statistical analysis

The independent sample t-test is a widely used statistical method in research to determine the impact of physical

education on improving students' interpersonal communication skills. This method allows researchers to compare the means of two independent groups to assess whether there is a significant difference between them. Utilizing the independent sample t-test in the analysis of the impact of physical education on students' interpersonal communication skills enables researchers to make evidence-based conclusions regarding the effectiveness of physical education programs. By comparing the communication competence of students who have received comprehensive physical education with those who have not, researchers can quantify the specific improvements attributable to physical education.

The findings from independent sample t-tests provide valuable insights into the efficacy of physical education in enhancing students' interpersonal communication skills, thus informing educators and policymakers about the measurable impact of integrating physical education into the broader curriculum. Through rigorous data analysis, the independent sample t-test contributes to the body of evidence supporting the importance of prioritizing physical education as a means of fostering students' interpersonal communication competencies. The incorporation of the independent sample t-test in research on the impact of physical education on students' interpersonal communication skills underscores the significance of empirical evidence in shaping educational policies and practices.

Results

This research aims to explore the impact of implementing physical education in schools on students' interpersonal communication skills. Physical education, as an important component in the curriculum, is expected to not only improve physical health, but also students' social and emotional abilities. In this research, interpersonal communication skills were analyzed separately in two main groups, namely Vocational School (SMK) and Senior High School (SMA) students. This study aims to identify which groups show more significant improvements in interpersonal communication skills as a result of implementing physical education.

Apart from that, this research also pays attention to the gender variable in its analysis. Thus, the results of this research will provide a comprehensive picture of the differences in the impact of physical education on interpersonal communication skills between male and female students. This research uses a quantitative approach with survey and observation methods to collect data. It is hoped that the research results can provide an important contribution to the development of the physical education curriculum in schools and provide insight for educators and educational policy makers in efforts to improve students' interpersonal communication skills through physical education.

Type of School

Based on table 1, the results of the Independent Samples t Test found that there were significant differences between the Vocational High School (SMK) and Senior High School (SMA) groups. This is based on the p value in the two-sided test (Two-Sided p) which is smaller than 0.001.

This suggests that the observed differences between the two groups are not the result of chance, but rather likely reflect

Table 1. Independent Samples Test Results based on Differences in School Type

		Levene's Test		t-test				
		F	Sig.	t	df	Sig (2 tailed)	MD	SED
Total	Equal variances assumed	0.017	0.897	3.8	392.0	<0.001	3.730	0.978
	Equal variances not assumed			3.7	319.4	<0.001	3.730	0.987

real and substantial differences. A very small p value (<0.001) indicates that the chance of this difference occurring by chance is very small, so it can be concluded that the difference between the Vocational School and Senior High School groups is statistically significant.

From the results above, it is known that there is indeed a significant difference between the results of high school and vocational school students. In table 2 below you can see the average value for each group.

Table 2. Group Statistics

	School Type	N	Mean	SD	SEM
Total	Vocational School	155	100.01	9.716	0.780
	Senior High School	239	96.28	9.334	0.604

Apart from that, based on these results an average value was also obtained for each group. In the Vocational School (SMK) group, the average obtained was 100.01, while in the Senior High School (SMA) group, the average obtained was 96.28. This means that the Vocational School group has a better average even though the average difference is only 3.73 between the two groups. So, although these mean differences are not very large, statistical tests show that they are statistically significant. In other words, the average difference of 3.73 points is enough to conclude that there is a real difference between the performance of the Vocational School and Senior High School groups.

Gender

Based on table 1, the results of the Independent Samples t Test found that there was significant difference between men and women in terms of interpersonal communication skills. This is based on the p value for the two-sided test (Two-Sided p) which is 0.002. A p value of 0.002 indicates that the observed differences between male and female students are very unlikely to occur by chance, and the differences are statistically significant.

In other words, gender has a significant influence on interpersonal communication skills resulting from the implementation of physical education at school. This research shows that there are real differences between the interpersonal communication skills of male and female

students, which can provide additional insight into developing physical education programs that are more effective and appropriate to the needs of each group.

From the results above, it is known that there are indeed significant differences between results based on gender. In table 4 below you can see the average gender.

Table 4. Group Statistics

	Gender	N	Mean	SD	SEM
Total	Men	183	96.16	9.221	0.682
	Woman	211	99.12	9.819	0.676

Apart from that, based on these results an average value was also obtained for each gender group. In the male group, the average obtained was 96.16, while in the female group, the average obtained was 99.12. This means that the female group has a better average even though the average difference is only 2.96 between the two groups. Although this mean difference is not very large, a p value of 0.002 indicates that the difference is statistically significant. This means that interpersonal communication skills arising from the implementation of physical education are better for female students compared to male students.

The results of this study confirm that both school type (Vocational School vs. Senior High School) and gender (male vs. female) have a significant impact on interpersonal communication skills. Specifically: (1) Vocational School students have slightly higher average interpersonal communication skills than Senior High School students; (2) Female students have higher average interpersonal communication skills than male students. These results can be used to direct efforts to develop more effective physical education programs, taking into account differences between school type and gender to improve interpersonal communication skills among students.

Discussion

Based on the research results, it is evident that there are notable differences in the interpersonal communication skills of high school and vocational school students as a result of implementing physical education at school. The independent sample t test showed a two-sided p-value of

Table 3. Independent Sample Test Results Based on Gender Differences

		Levene's Test		t-test				
		F	Sig.	t	df	Sig (2 tailed)	MD	SED
Total	Equal variances assumed	1.75	0.186	-3.07	392.0	0.002	-2.960	0.964
	Equal variances not assumed			-3.08	389.5	0.002	-2.960	0.960

< 0.001, indicating significant differences. Additionally, there is a significant difference based on gender, with a p-value of 0.002. Both results achieved a significance level of < 0.05, highlighting the importance of physical education in enhancing students' interpersonal communication skills. This emphasizes the need for further exploration and development of physical education programs for students to cultivate these vital skills.

Further exploration and development of physical education programs is crucial for students to cultivate vital interpersonal communication skills (Bolotnikov et al., 2020; Clements & Kuperberg, 2008). In addition to the statistical significance of the results, it is important to consider the practical implications of these findings. Understanding and improving interpersonal communication skills can have a profound impact on students' academic achievements, career prospects, and overall well-being (Balcar & Dokoupilová, 2021; Martín, 2014b). Investing in physical education not only contributes to the physical health of students but also plays a significant role in their social and emotional development (Kalina et al., 2018; Sutherland & Parker, 2020). By providing opportunities for students to engage in teamwork, conflict resolution, and effective communication, physical education can empower them with essential life skills that extend far beyond the classroom (Hou, 2011; Madrona et al., 2019).

In today's interconnected world, the ability to communicate effectively is more important than ever (Cortellazzo et al., 2019). As educators and policymakers, it is imperative to recognize the value of physical education in equipping students with the tools they need to succeed in an increasingly complex and evolving society. By fostering a supportive environment that prioritizes the holistic development of students, schools can create a foundation for lifelong success (Tarigan et al., 2023). Moving forward, it is essential to continue researching and implementing innovative approaches to integrate physical education into the overall educational curriculum. By doing so, we can ensure that students receive a well-rounded education that not only focuses on academic knowledge but also prioritizes the acquisition of essential interpersonal communication skills (Mckenzie & Lounsbery, 2009; Özkara, 2018). As educators and policymakers continue to recognize the value of physical education in students' development, it is essential to prioritize the integration of physical education into the overall educational curriculum (El-Sherif, 2014; Mckenzie & Lounsbery, 2009). A comprehensive approach to education must encompass not only academic knowledge but also the cultivation of essential interpersonal communication skills.

One effective way to achieve this integration is through the establishment of collaborative programs that combine physical education with other subjects such as language arts, social studies, or even technology (Marttinen et al., 2017; Wilson-Parish & Parish, 2016). These interdisciplinary approaches can provide students with opportunities to apply their communication skills in various contexts, thereby reinforcing and improving their abilities (Deneme & Ada, 2012; Spelt et al., 2009). Furthermore, the implementation of extracurricular activities that emphasize teamwork and communication, such as team sports or group fitness challenges, can complement the formal physical education curriculum. These activities not only promote physical

wellness but also offer students practical opportunities to apply and enhance their interpersonal communication skills in real-life scenarios (Eime et al., 2013; Slentz & Chase, 2003).

In addition, educators can consider incorporating technology and digital tools into physical education to engage students in interactive communication exercises (Lambert, 2016; Wintle, 2019). Platforms for video analysis, virtual teamwork, and communication simulations can provide a modern and dynamic approach to teaching interpersonal communication within the physical education framework. As we move forward, it is crucial for educational institutions to engage in ongoing research to identify the most effective methods for integrating physical education into the broader curriculum (Humphries et al., 2011; Marttinen et al., 2017; Wilson-Parish & Parish, 2016). By continually evolving and adapting the approach to physical education, schools can ensure that students are equipped with the necessary interpersonal communication skills to thrive in all aspects of their lives (Kulinna, 2008; Mckenzie & Lounsbery, 2009).

Incorporating physical education into the broader curriculum not only enhances students' physical well-being but also equips them with essential interpersonal communication skills, unleashing their potential for success in an increasingly complex and interconnected world (Clements & Kuperberg, 2008; Kalina et al., 2018; Lamb et al., 2016). Research has shown that collaborative programs integrating physical education with subjects such as language arts, social studies, and technology can provide students with diverse opportunities to enhance their communication skills in real-world contexts.

Moreover, extracurricular activities emphasizing teamwork and communication, such as team sports or group fitness challenges, complement the formal physical education curriculum by offering practical scenarios for students to apply and refine their interpersonal communication abilities (Gabler & Kaufman, 2006; Marsh, 1992). Additionally, leveraging technology and digital tools in physical education, such as video analysis, virtual teamwork platforms, and communication simulations, can provide a dynamic approach to teaching interpersonal communication within the framework of physical education (Wintle, 2019). Educational institutions must continue to engage in ongoing research to identify the most effective methods for integrating physical education into the broader curriculum (Bryant et al., 2021; Dyson, 2014). By evolving and adapting the approach to physical education, schools can ensure that students are equipped with the necessary interpersonal communication skills to thrive in all aspects of their lives. This ongoing commitment to the development and implementation of innovative approaches to physical education will play a crucial role in shaping students into well-rounded individuals capable of navigating the challenges of the modern world.

Conclusions

The research utilizing the Interpersonal Communication Competence Scale (ICCS) and the independent sample t-test provides compelling evidence of the positive impact of physical education on improving students' interpersonal communication skills. By integrating physical education into the broader curriculum and utilizing data-driven analyses, edu-

cators and policymakers can draw several important conclusions regarding the significance of prioritizing interpersonal communication skills in students' overall development.

Firstly, the utilization of the ICCS has revealed that comprehensive physical education programs not only contribute to students' physical well-being but also play a crucial role in fostering essential interpersonal communication skills. This highlights the multifaceted benefits of incorporating physical education into the educational framework, emphasizing its role in not only promoting physical health but also in nurturing vital communication competencies.

Moreover, the findings from the independent sample t-test demonstrate that students who have received comprehensive physical education exhibit significant improvements in interpersonal communication skills compared to those who have not. This underscores the measurable impact of physical education on students' communication competencies, providing empirical evidence to support the integration of physical education into the broader curriculum.

Furthermore, the convergence of insights from the ICCS and the independent sample t-test underscores the holistic approach to student development. It emphasizes the interconnected nature of physical well-being and interpersonal communication skills, highlighting the need for a comprehensive educational framework that addresses both aspects to ensure students are well-prepared for the complexities of the modern world.

In conclusion, the research's findings support the ongoing commitment to the integration of physical education into the broader curriculum as a means of equipping students with essential interpersonal communication skills. By drawing these conclusions from the data, educational institutions can continue to refine and enhance their approach to physical education, ultimately empowering students to thrive in all aspects of their lives.

Conflict of interest

The authors state that no commercial or financial ties that might be considered a possible conflict of interest existed during the conduct of the study.

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References

- Hacıaferoğlu, S. (2022). Investigation of communication skills perceived by students from instructors. *Physical Education of Students*, 26(4), 173-179. <https://doi.org/10.15561/20755279.2022.0402>
- Mas'amah, M., Leuape, E. S., Nafie, J. A., Jelahun, F. E., & Nggaba, S. N. (2023). Political Communication Practice of Cipayang Student Organization Kupang- NTT Province. *Komunikator*, 15(1), 103-117. <https://doi.org/10.18196/jkm.16647>
- Stoddart, A. L., & Humbert, M. L. (2021). Teachers' Perceptions of Physical literacy. *Curriculum Journal*, 32(4), 741-757. <https://doi.org/10.1002/curj.107>
- Hawani, A., Bouzid, M. S., & Mrayah, M. (2020). The Significance of Professional Communication Skills for Future Tunisian Physical Education Teachers. *Journal of Education, Society and Behavioural Science*, 33(9), 34-41. <https://doi.org/10.9734/jesbs/2020/v33i930256>
- Laufs, J., & Waseem, Z. (2020). Policing in pandemics: A systematic review and best practices for police response to COVID-19. *International Journal of Disaster Risk Reduction*, 51(August), 101812. <https://doi.org/10.1016/j.ijdrr.2020.101812>
- Lamb, P., Firbank, D., & Aldous, D. (2016). Capturing the world of physical education through the eyes of children with autism spectrum disorders. *Sport, Education and Society*, 21(5), 698-722. <https://doi.org/10.1080/13573322.2014.941794>
- Chermak, S., & Weiss, A. (2005). Maintaining legitimacy using external communication strategies: An analysis of police-media relations. *Journal of Criminal Justice*, 33(5), 501-512. <https://doi.org/10.1016/j.jcrimjus.2005.06.001>
- Nichols, B. G., Nichols, L. M., Poetker, D. M., & Stadler, M. E. (2014). Operationalizing professionalism: A meaningful and practical integration for resident education. *Laryngoscope*, 124(1), 110-115. <https://doi.org/10.1002/lary.24184>
- Sun, H. (2011). The 3-3-3 framework and 7P model for teaching creativity, innovation and entrepreneurship. *Journal of Chinese Entrepreneurship*, 3(2), 159-166. <https://doi.org/10.1108/17561391111144582>
- Park, K. H., Kim, A. R., Yang, M. A., Lim, S. J., & Park, J. H. (2021). Impact of the COVID-19 pandemic on the lifestyle, mental health, and quality of life of adults in South Korea. *PLoS ONE*, 16(2), 1-13. <https://doi.org/10.1371/journal.pone.0247970>
- Sutherland, S., & Parker, M. (2020). Responding to Trauma in and through Physical Education. *Journal of Physical Education, Recreation and Dance*, 91(9), 16-21. <https://doi.org/10.1080/07303084.2020.1811621>
- Primo, L., González-Hernández, J., Yang, Y., & López de Subijana, C. (2023). Predicting social skills in disadvantaged Chinese high school students through physical education. *Frontiers in Psychology*, 14(April), 1-9. <https://doi.org/10.3389/fpsyg.2023.1149223>
- White, D. K., Jakiela, J., Bye, T., Aily, J., & Voinier, D. (2023). Stepping Forward: A Scoping Review of Physical Activity in Osteoarthritis. *Journal of Rheumatology*, 50(5), 611-616. <https://doi.org/10.3899/jrheum.220728>
- Amadi, G., & Kufre Paul, A. (2017). Influence of Student-Teacher Communication on Students' Academic Achievement for Effective Teaching and Learning. *American Journal of Educational Research*, 5(10), 1102-1107. <https://doi.org/10.12691/education-5-10-12>
- Kourkouta, L., & Papatheanasiou, I. (2014). Communication in Nursing Practice. *Materia Socio Medica*, 26(1), 65. <https://doi.org/10.5455/msm.2014.26.65-67>
- Guan, Y. (2023). Research on the Collaborative Path of Integrating Ideological and Political Content into College Physical Education Teaching. *Curriculum and Teaching Methodology*, 6(10), 130-134. <https://doi.org/10.23977/curtm.2023.061020>

- Bhat, R. A. (2023). The Impact of Technology Integration on Student Learning Outcomes: A Comparative Study. *International Journal of Social Science, Educational, Economics, Agriculture Research and Technology (IJSET)*, 2(9), 592-596. <https://doi.org/10.54443/ijset.v2i9.218>
- Ganan, D., Caballe, S., Conesa, J., Barolli, L., Kulla, E., & Spaho, E. (2014). A systematic review of multimedia resources to support teaching and learning in virtual environments. *Proceedings - 2014 8th International Conference on Complex, Intelligent and Software Intensive Systems, CISIS 2014*, July, 249-256. <https://doi.org/10.1109/CISIS.2014.35>
- Zin, M. Z. M., Sakat, A. A., Ahmad, N. A., & Bhari, A. (2013). Relationship Between the Multimedia Technology and Education in Improving Learning Quality. *Procedia - Social and Behavioral Sciences*, 90(January), 351-355. <https://doi.org/10.1016/j.sbspro.2013.07.102>
- Yang, C., Chen, R., Chen, X., & Lu, K. H. (2021). The Efficiency of Cooperative Learning in Physical Education on the Learning of Action Skills and Learning Motivation. *Frontiers in Psychology*, 12(717528), 1-17. <https://doi.org/10.3389/fpsyg.2021.717528>
- Dina, G., & Dina, L. (2014). Direct Communication in Physical Education Classes. *Procedia - Social and Behavioral Sciences*, 117(January), 136-142. <https://doi.org/10.1016/j.sbspro.2014.02.191>
- Widyaningsih, H., Asmawi, M., & Tangkudung, J. (2020). The Influence of Teaching Skills and Effective Communication on The Professional Competencies of Physical Education Teachers. *Journal of Education, Health and Sport*, 10(1), 84-89. <https://doi.org/10.12775/jehs.2020.10.01.010>
- Altun, M., Kurtul, N., & Soykan, M. (2018). The Investigation of Communication Skills of Students at Different Departments at a State University in Turkey. *International Journal of Scientific Research and Management (IJSRM)*, 6(09), 288-293. <https://doi.org/10.18535/ijssrm/v6i9.sh05>
- Bailey, R. (2006). Physical education and sport in schools: A review of benefits and outcomes. *Journal of School Health*, 76(8), 397-401. <https://doi.org/10.1111/j.1746-1561.2006.00132.x>
- Sullivan, P. A. (1993). Communication Skills Training for Interactive Sports. *Sport Psychologist*, 7, 79-91. <https://doi.org/10.1123/tsp.7.1.79>
- Hulbert, J., Gibbs, M., Hewing, P., & Underwood, R. (1987). How to Teach Interpersonal Communication Techniques in a Basic Business Communication Class. *Business Communication Quarterly*, 50(4), 24-28. <https://doi.org/10.1177/108056998705000409>
- Jiang, T. (2018). Research on the Structure and Measurement of Communication Capabilities of Enterprise Managers. *SSMME*, 179-182. <https://doi.org/10.23977/ssmme.2018.62241>
- Lolli, J. C. (2013). Interpersonal communication skills and the young hospitality leader: Are they prepared? *International Journal of Hospitality Management*, 32(1), 295-298. <https://doi.org/10.1016/j.ijhm.2012.02.010>
- Dyson, B. (2014). Quality physical education: A commentary on effective physical education teaching. *Research Quarterly for Exercise and Sport*, 85(2), 144-152. <https://doi.org/10.1080/02701367.2014.904155>
- Madrona, P. G., Gutiérrez-Marín, E. C., Cupani, M., Samalot-Rivera, A., Díaz-Suárez, A., & López-Sánchez, G. F. (2019). The effects of an appropriate behavior program on elementary school children social skills development in physical education. *Frontiers in Psychology*, 10(SEP), 1-8. <https://doi.org/10.3389/fpsyg.2019.01998>
- Iksan, Z. H., Zakaria, E., Meerah, T. S. M., Osman, K., Lian, D. K. C., Mahmud, S. N. D., & Krish, P. (2012). Communication Skills among University Students. *Procedia - Social and Behavioral Sciences*, 59(October), 71-76. <https://doi.org/10.1016/j.sbspro.2012.09.247>
- Martín, R. D. (2014a). The Importance of Communication Competency for Employability. *Procedia - Social and Behavioral Sciences*, 139(January), 387-394. <https://doi.org/10.1016/j.sbspro.2014.08.024>
- Wayne, F. S., Mitchell, R. B., & Scriven, J. D. (1992). Vital Communication Skills and Competencies in the Workforce of the 1990s. *Journal of Education for Business*, 67(3), 141-146. <https://doi.org/10.1080/08832323.1992.10117533>
- Double, K. S., McGrane, J. A., & Hopfenbeck, T. N. (2020). The Impact of Peer Assessment on Academic Performance: A Meta-analysis of Control Group Studies. *Educational Psychology Review*, 32(2), 481-509. <https://doi.org/10.1007/s10648-019-09510-3>
- El-Sherif, J. L. (2014). Student Voice: Student Choice and Participation in Physical Education. *Strategies*, 27(5), 8-11. <https://doi.org/10.1080/08924562.2014.938875>
- Shin, E. K., Wilkins, E. A., & Ainsworth, J. (2007). The Nature and Effectiveness of Peer Feedback during an Early Clinical Experience in an Elementary Education Program. *Action in Teacher Education*, 28(4), 40-52. <https://doi.org/10.1080/01626620.2007.10463428>
- Mills, J. K. A., Dalleywater, W. J., & Tischler, V. (2014). An assessment of student satisfaction with peer teaching of clinical communication skills. *BMC Medical Education*, 14(1). <https://doi.org/10.1186/1472-6920-14-217>
- Hodder, R. V., Rivington, R. N., Calcutt, L. E., & Hart, I. R. (1989). The effectiveness of immediate feedback during the Objective Structured Clinical Examination. *Medical Education*, 23(2), 184-188. <https://doi.org/10.1111/j.1365-2923.1989.tb00884.x>
- Nofziger, A. C., Naumburg, E. H., Davis, B. J., Mooney, C. J., & Epstein, R. M. (2010). Impact of peer assessment on the professional development of medical students: A qualitative study. *Academic Medicine*, 85(1), 140-147. <https://doi.org/10.1097/ACM.0b013e3181c47a5b>
- Simonsmeier, B. A., Peiffer, H., Flaig, M., & Schneider, M. (2020). Peer Feedback Improves Students' Academic Self-Concept in Higher Education. *Research in Higher Education*, 61(6), 706-724. <https://doi.org/10.1007/s11162-020-09591-y>
- Martineau, B., Mamede, S., St-Onge, C., & Bergeron, L. (2016). The Influence of Peer Feedback on the Acquisition of Physical-Examination Skills. *Health Professions Education*, 2(2), 106-113. <https://doi.org/10.1016/j.hpe.2016.07.002>
- Zhou, Y., De Shao, W., & Wang, L. (2021). Effects of feedback on students' motor skill learning in physical education: A systematic review. *International Journal of Environmental Research and Public Health*, 18(12). <https://doi.org/10.3390/ijerph18126281>
- Kemendikbud (2018). Peraturan Menteri Pendidikan dan Kebudayaan RI Nomor 34 Tahun 2018 Tentang Standar

- Nasional Pendidikan Sekolah Menengah Kejuruan/ Madrasah Aliyah Kejuruan. Kemendikbud, 1-1369. (In Indonesian).
- Bolotnikov, A. A., Imangulov, R. S., & Gimadeev, R. N. (2020). Competences of Social Interaction and their Role in the Process of Physical Education. *FICEHS*, (19), 632-635. <https://doi.org/10.2991/aebmr.k.200114.146>
- Clements, R., & Kuperberg, M. (2008). Reaching Our Goals Through Effective Communication. *Journal of Physical Education, Recreation & Dance*, 79(3), 4-7. <https://doi.org/10.1080/07303084.2008.10598140>
- Balcar, J., & Dokoupilová, L. (2021). Communication and language skills pay off, but not everybody needs them. *International Journal of the Sociology of Language*, 2021(270), 59-93. <https://doi.org/10.1515/ijsl-2020-0021>
- Martín, R. D. (2014b). The Importance of Communication Competency for Employability. *Procedia - Social and Behavioral Sciences*, 139, 387-394. <https://doi.org/10.1016/j.sbspro.2014.08.024>
- Kalina, I., Golubev, A., & Aidarov, R. (2018). The Role of Physical Education in Developing Students' Social and Psychological Qualities of a Personality. *SHS Web of Conferences*, 50(01075), 1-4. <https://doi.org/10.1051/shsconf/20185001075>
- Hou, L. (2011). Research on the developmental physical education model integrated knowledge, belief and practice. *ITME 2011 - Proceedings: 2011 IEEE International Symposium on IT in Medicine and Education*, 1, 160-164. <https://doi.org/10.1109/ITiME.2011.6130807>
- Cortellazzo, L., Bruni, E., & Zampieri, R. (2019). The role of leadership in a digitalized world: A review. *Frontiers in Psychology*, 10(AUG), 1-21. <https://doi.org/10.3389/fpsyg.2019.01938>
- Tarigan, H., Tarigan, B. S., & Iwandana, D. T. (2023). Efforts to Increase the Cognitive and Physical Abilities of Kindergarten Students. *COMPETITOR: Jurnal Pendidikan Kepelatihan Olahraga*, 15(1), 156. <https://doi.org/10.26858/cjpko.v15i1.43994>
- Mckenzie, T. L., & Lounsbery, M. A. F. (2009). School Physical Education: The Pill Not Taken. *American Journal of Lifestyle Medicine*, 3(3), 219-225. <https://doi.org/10.1177/1559827609331562>
- Özkara, A. B. (2018). Physical Education in Eu Schools and Turkey: A Comparative Study. *Comparative Professional Pedagogy*, 8(2), 101-106. <https://doi.org/10.2478/rpp-2018-0026>
- Marttinen, R. H. J., McLoughlin, G., Fredrick, R., & Novak, D. (2017). Integration and Physical Education: A Review of Research. *Quest*, 69(1), 37-49. <https://doi.org/10.1080/00336297.2016.1150864>
- Wilson-Parish, N., & Parish, A. (2016). How Integration Can Benefit Physical Education: Column Editor: Anthony Parish. *Strategies*, 29(6), 34-36. <https://doi.org/10.1080/08924562.2016.1234157>
- Deneme, S., & Ada, S. (2012). On Applying the Interdisciplinary Approach in Primary Schools. *Procedia - Social and Behavioral Sciences*, 46, 885-889. <https://doi.org/10.1016/j.sbspro.2012.05.217>
- Spelt, E. J. H., Biemans, H. J. A., Tobi, H., Luning, P. A., & Mulder, M. (2009). Teaching and learning in interdisciplinary higher education: A systematic review. *Educational Psychology Review*, 21(4), 365-378. <https://doi.org/10.1007/s10648-009-9113-z>
- Eime, R. M., Young, J. A., Harvey, J. T., Charity, M. J., & Payne, W. R. (2013). A systematic review of the psychological and social benefits of participation in sport for adults: Informing development of a conceptual model of health through sport. *International Journal of Behavioral Nutrition and Physical Activity*, 10. <https://doi.org/10.1186/1479-5868-10-135>
- Slentz, T. C., & Chase, M. A. (2003). Climbing Mount Everest a New Challenge for Physical Education Adventure Education. *Journal of Physical Education, Recreation & Dance*, 74(4), 41-43. <https://doi.org/10.1080/07303084.2003.10609201>
- Lambert, C. (2016). Technology Has a Place in Physical Education. *Journal of Physical Education, Recreation & Dance*, 87(9), 58-60. <https://doi.org/10.1080/07303084.2016.1227200>
- Wintle, J. (2019). Digital technology in physical education: global perspectives. *Sport, Education and Society*, 24(6), 665-667. <https://doi.org/10.1080/13573322.2019.1618103>
- Humphries, C. A., Bidner, S., & Edwards, C. (2011). Integrated Learning with Physical Education and Music. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, 84(5), 174-179. <https://doi.org/10.1080/00098655.2010.543192>
- Kulinna, P. H. (2008). Models for Curriculum and Physical Education. *The Elementary School Journal*, 108(3), 219-227. <https://doi.org/10.1086/529104>
- Gabler, J., & Kaufman, J. (2006). Chess, Cheerleading, Chopin: What Gets You Into College? *Contexts*, 5(2), 45-49. <https://doi.org/10.1525/ctx.2006.5.2.45>
- Marsh, H. W. (1992). Extracurricular Activities: Beneficial Extension of the Traditional Curriculum or Subversion of Academic Goals? *Journal of Educational Psychology*, 84(4), 553-562. <https://doi.org/10.1037/0022-0663.84.4.553>
- Bryant, L., Burson, S. L., Fisher, J., Killian, C. M., Mulhearn, S. C., Nesbitt, D., Pfladderer, C. D., & Castelli, D. M. (2021). Evidence Supporting the Essential Components of Physical Education as a Measure of Quality. *Research Quarterly for Exercise and Sport*, 92(2), 259-269. <https://doi.org/10.1080/02701367.2021.1883505>

Фізичне виховання як засіб покращення навичок міжособистісного спілкування 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., 4 табл., 66 джерел.

Історія питання. Навички міжособистісного спілкування мають значний вплив на реалізацію навчального процесу в школі, на якому необхідно акцентувати увагу. Отже, забезпечення процедури постійного оцінювання учнів має важливе значення для досягнення оптимальних навичок міжособистісного спілкування.

Мета дослідження. Дане дослідження мало на меті вивчити вплив впровадження фізичного виховання на навички міжособистісного спілкування в учнів старших класів середньої загальноосвітньої школи (СЗШ) та професійно-технічних навчальних закладів (ПТНЗ). Обидва типи навчальних закладів мають відмінні характеристики. У старшій школі більше уваги приділяється безперервній освіті, в той час як у професійно-технічних навчальних закладах основний акцент ставиться на підготовці випускників до трудової діяльності.

Матеріали та методи. У дослідженні застосовано кількісний та описовий підхід, в якості досліджуваної вибірки обрано учнів старших класів шкіл та професійно-технічних навчальних закладів. Шкала міжособистісної комунікативної компетентності (ШМКК) є дослідницьким інструментом, застосованим у даній роботі.

Результати. На підставі отриманих результатів дослідження можна стверджувати, що існують відмінності в показниках навичок міжособистісного спілкування між учнями старших класів та професійно-технічних навчальних закладів порівняно з результатами впровадження фізичного виховання в школі. Про це свідчать результати дослідження з використанням t-критерію для незалежних вибірок (двостороннє р-значення) < 0,001. Крім того, можна також спостерігати, що за статевою ознакою (чоловіки та жінки) отримано значення 0,002. Обидва результати мають рівень значущості < 0,05.

Висновки. Як показують результати дослідження, навички міжособистісного спілкування в учнів професійно-технічних навчальних закладів є більш розвиненими, ніж у старшокласників.

Ключові слова: фізичне виховання, міжособистісне спілкування, школа, учень, професійно-технічний навчальний заклад, старші класи середньої школи.

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Determining the Impact of Menstrual Cycle on Collegiate Athletes: Self-reported Health Issues, Sports Performance, and Willingness to Discuss Regarding Menstruation

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Abstract

Background. Gaining a comprehensive understanding of the menstrual cycle, its associated health concerns, and the subsequent effects on athlete performance could facilitate the formulation of educated and tailored strategies for training and participating in competitive sports. In turn, this can decrease the probability of injuries, maintain psychological well-being, and ultimately enhance athlete performance.

Objectives. The study aimed to investigate the perspective of collegiate student-athletes related to health issues and sports performance during their menstrual period, both in terms of training and competition, as well as the athletes' willingness to discuss pertaining their menstrual cycle.

Materials and methods. Our study included 115 female student-athletes participating in land-based individual/team sports ($n = 95$) and a combination of land/water-based sports ($n = 20$). A questionnaire was used to collect data for this cross-sectional study, which was undertaken and completed by the participants. A descriptive analysis was performed, with results reported in frequency and percentage, followed by the Wilcoxon rank-sum test (Mann-Whitney) to analyze the mean differences between the training participation groups during menstruation.

Results. In general, all athletes experienced several health issues, with abdominal pain and lower back pain being the most prevalent. Furthermore, nearly all of them (95.33 %) experienced pain on the first day of their periods. Menstruation also influences the performance of female athletes during exercise (70.43 %) and competition (73.91 %), causing increased fatigue and reduced endurance in the majority of them. Additionally, there is a significant difference between the context of training engagement and the number of weekly exercise sessions (0.011) during the menstrual cycle.

Conclusions. Menstruation significantly affects the health and performance of female athletes, both during training and competition. Coaches and athletes must comprehend the menstrual cycle to address this issue effectively. It is crucial that coaches and athletes possess a comprehensive understanding of the menstrual cycle in order to effectively address this issue. Moreover, involving medical professionals and sports nutritionists in managing menstrual cycles is also another strategy for enhancing athlete performance.

Keywords: period, health concern, follicular phase, female athletes, exercise, competition.

Introduction

In recent decades, there has been a notable rise in female involvement in sports, including a spectrum ranging from physical activity to participation in elite athlete competitions,

which can be attributed to heightened efforts and resources dedicated to the advancement of women's professional sports (Fink, 2015; Forsyth & Roberts, 2018). This is evidenced by the significantly increased number of women's participation in competing in the Olympics, by 34 % of the total participants at the 1996 Olympics in Atlanta, then increasing to 45 % at the 2016 Rio Olympics, and it is estimated to reach 48.8 % at the Tokyo 2020 Olympics (International Olympic Committee, 2020).

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Physical activity or exercise can decrease anxiety and depression (Mikkelsen et al., 2017), cardiovascular fitness (Lavie et al., 2015), reproductive health (Harrison et al., 2016; Orio et al., 2013), including decreasing weight for both men and women (Caudwell et al., 2014; Swift et al., 2014). However, women in sports are sometimes side-lined because they are considered more challenging to learn than men due to their higher levels of hormonal complexity (Holtzman & Ackerman, 2021). It is due to the physiological differences between men and women in terms of menstrual cycles, which are under the control of the hormonal system, and this cycle affects various aspects of health, well-being, and sports performance (Lebrun, Joyce, & Constantini, 2013; Mountjoy et al., 2014; Ön, Diker, & Özkamçı, 2014). The menstrual cycle has been reported as an essential biological rhythm affecting female reproduction and is also considered for optimizing exercise, enhancing athletes' adaptive responses (Julian & Sargent, 2020), and athlete performance (Oosthuyse & Bosch, 2010). Constantini et al. (2005) identified a number of exercise performance parameters—including metabolic, respiratory, cognitive function, cardiovascular, orthopaedic, and response to ergogenic aid—that are affected by the menstrual cycle, which affect both aerobic and anaerobic strength and overall performance during exercise.

In a part of a review related to the literature on the impact of physical activity on women's physiology, research conducted by Loveless (2017) and Meczekalski (2014) emphasizes that the majority of women who are menstruating and performing several types of exercise experience an assortment of menstrual cycle disorders. This indicates that the menstrual cycle negatively impacts both physically and psychologically women's lives and daily activities (Mountjoy et al., 2014). Furthermore, this finding aligns with the research reported by Findlay et al. (2020), which reveals that 51 % of athletes perceive menstruation as an impediment to their training and performance, and 93 % of female athletes experience adverse physical and psychological symptoms associated with their menstrual cycle. Specific instances indicate that approximately 75 % of women in their reproductive years' experience menstrual discomfort; this condition is particularly prevalent among young women; it is also experienced by approximately 90 % of Australian adolescents who experience menstrual pain (Parker, Sneddon, & Arbon, 2010; Subasinghe et al., 2016). Additionally, 58 % of teenage volleyball athletes also experience pain prior to the onset of menstruation, while 66 % following menstruation (Wodarska et al., 2013).

During the premenstrual and menstrual phases, estrogen and progesterin levels decrease, resulting in psychological alterations, in particular irritability, and depression, along with unpleasant physical symptoms like breast tension and abdomen pain, which have been found to have a detrimental impact on sports performance (Prado Seoane, 2013). The fluctuations in estrogen and progesterone levels during the menstrual cycle have a wide range of intricate and multifaceted impacts on many physiological systems, including cardiovascular, pulmonary, metabolic, and neuro-muscular components (Ansdell et al., 2019). Hence, understanding the menstrual cycle's impact on women's sports is essential for athletes and coaches to do the right exercises and ensure optimal health and well-being (Knowles et al., 2019).

Notwithstanding numerous challenges faced by female athletes during their menstrual cycle and the fact that the

gender gap has decreased in sports participation, women are still underrepresented (4-13 %) in scientific research on sports health or sports medicine (Bruinvels et al., 2017; Costello, Bieuzen, & Bleakley, 2014; Cowley, Olenick, McNulty, & Ross, 2021), and urgently require for further investigation (Carmichael, Thomson, Moran, & Wycherley, 2021), particularly among student-athletes. Therefore, this study examined the perspective of collegiate student-athletes related to health concerns and sports performance during their menstrual period, both in terms of training and competition, as well as the athletes' willingness to discuss pertaining their menstrual cycle.

Materials and Methods

Study Participants

Our cross-sectional study utilized a convenience sample to recruit participants from a several universities in Indonesia. Only student-athletes who have competed at the regional, national, and international levels were included in this study. We excluded data from respondents ($n = 6$) who were not student-athletes based on the criteria and data cleansing procedure. Hence, 115 student-athletes qualified participated in this study.

Study Organization

This study's questionnaire instrument consisted of four sections: socio-demographics (information pertaining to age, sports, duration of practice in one week, duration of practice per day, the cumulative number of menstruations in a year, participation in training and competition during the menstrual period, level of competition, medals won during menstruation, menstrual cycle, and medication usage during menstruation both in the time of training and competition, were included); the perspective of student-athletes regarding health issues experienced during menstruation. Furthermore, a questionnaire regarding the impact of menstruation on their performance which includes what aspects of training or competition are impacted by menstrual symptoms, including training modifications based on menstruation, as well as information regarding with whom they feel sufficiently at ease to discuss their menstrual cycle which adapted from research conducted by Armor et al. (2020) nutrition, skills and tactics. This questionnaire was distributed over WhatsApp to individuals and groups, with a link to the survey's URL.

The participants were then instructed to complete the self-administrated online questionnaire independently. Furthermore, participants were given detailed instructed to read the questions attentively and answer them according to their condition. It was highlighted that the respondent should select the answer deemed most appropriate based on their assessment related to health issues during menstruation and their sports performance. Additionally, we also remind the participants that there are no right or wrong answers. This study took about 15 to 20 minutes for participants to complete the questions.

Statistical Analysis

In this study, we employed Microsoft Excel to collect and clean data. Subsequently, Stata (version 14) was used to perform statistical analysis. The descriptive data are

reported in frequency and percentage and displayed in tables and graphs afterwards. The Wilcoxon rank-sum test (Mann-Whitney) was then used to examine the mean differences between the training participation groups during menstruation, with a significance level of $p = 0.05$.

Results

Socio-demographic characteristics

Table 1 outlined that the participants in this study were female collegiate-student athletes, with a large number of their ages ranging from 20 to 23 years (73 %), height 150 to 160 cm (67.83 %), body weight 50 to 59 kg (53.91 %), and having a normal body mass index (75.65 %). Most of the student-athletes participated in team sports (land-based), exercised three to four times per week, and duration of their daily exercise for one to two hours per day, with a proportion of the participants 51.3 %, 65.22 %, and 77.39 %, respectively.

Furthermore, the majority of female athletes (67.83 %) experienced menstruation between 12 and 15 times per year, 66.96 % of participants had regular menstrual cycles, and 46.09 % routinely engaged in high-intensity exercise during their menstrual periods. Nearly all athletes also (93.04 %) encountered pain either right prior to their periods (88.79 %) or on day one of their periods (95.33 %), and most of them reported do not take menstrual pain relievers (80.87 %) or taking medication to delay menstruation (82.61 %), while a minority of them (6.09 %) utilize medicine to delay menstruation who are combination (water-based) athletes. Moreover, the majority of participants engaged in training (58.26 %) and competitions during menstruation (65.22 %) and won medals (61.74 %) in most regional competitions (60.87 %).

Health issues among collegiate student-athlete during menstruation

The most common health concerns experienced by female collegiate student-athletes during menstruation were feeling abdominal pain/pain in the lower abdomen, lower back pain, feeling tired/easily tired, mood swings, and headache/dizziness, with a percentage of the participants 86.09 %, 66.09 %, 28.70 %, 22.92 %, respectively (Fig.1).

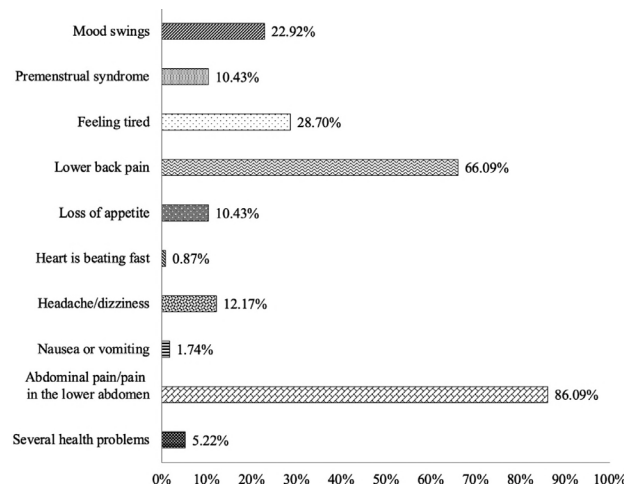


Fig. 1. Self-reported health issues encountered by student-athletes

Table 1. Socio-demographic characteristic of participants

Variables	N = 115	
	n	%
Age (year)		
16-19	31	27.0
20-23	84	73.0
Boddy Mass Index (BMI)		
Normal	87	75.65
Underweight	15	13.04
Overweight	13	11.30
Sport activity		
Team sport (land-based)	59	51.3
Individual sport (land-based)	36	31.3
Combination (water-based)	4	3.5
Combination (land-based)	16	13.9
Number of exercises in a week (days)		
3-4	75	65.22
5-6	40	34.78
Duration of daily exercises (hours)		
1-2	89	77.39
> 2	26	22.61
Cumulative number of menstruations in a year (times)		
5-8	1	0.87
9-11	36	31.30
12-15	75	67.83
Menstrual cycle		
Regular	77	58.26
Irregular	38	41.74
Menstrual cycle during high-intensity exercise		
Regular	53	66.96
Irregular	62	33.04
Menses pain		
Yes, with each period	107	93.04
No	8	6.96
Pain incidence*		
Day one of my menstrual	102	95.33
Right prior to my period beginning	95	88.79
Day two of my menstrual	98	91.59
My entire period	12	11.21
The third day of my menstruation and subsequent	9	8.41
Taking menstrual pain relievers		
Yes	22	19.13
Not	93	80.87
Medication usage to delay menstruation		
Yes	4	6.09
Not	96	82.61
Sometimes	15	11.3
Participating in training during menstrual period		
Always	67	58.26
Sometimes	48	41.74
Participating in competition during menstrual period		
Always	75	65.22
Sometimes	40	34.78
Medal during period		
With medals	71	61.74
Without medals	44	38.26
Competition level		
Regional	70	60.87
National	40	34.78
International	5	4.35

* Several responses are permitted and can contribute more than 100%

Menstrual cycle and athlete performance

The occurrence of menstruation presents unique challenges for female athletes. Our study revealed that most respondents reported being negatively affected by their performance both during training (70.43 %), competition (73.91 %), and commonly in the time of their period. They also feel tired more easily / have less endurance both during

Table 2. Impact of menstrual cycle on performance

The influence of menstruation on athlete performance	n	%
During exercise	n = 115	
Yes – negatively affected	81	70.43
No, I do not see any distinction	34	29.57
Part of the cycle affects exercise*		
During my menstrual cycle	81	70.43
A day or two before menstruation	60	52.17
One to two weeks preceding the onset of menstruation	30	26.09
Part of exercise is negatively affected*	n = 81	
Perceive lacking strength/unable to lift substantial amounts of weight	15	18.51
Experienced less coordinated or clumsier	10	12.35
Tired more easily/have less endurance	35	43.21
Can't concentrate on the instructions or tactics given by the coach during the match	8	9.88
Experience a lack of swiftness in activities that require rapidity	38	46.91
There exists a disparity in my energy levels	25	30.86
Worried that there will be blood stains on clothes/uniform	9	11.11
During competition	n = 115	
Yes – negatively affected	85	73.91
No, I do not see any distinction	30	26.09
Part of the cycle affects competition*		
During my menstrual cycle	85	73.91
A day or two before menstruation	50	43.48
One to two weeks preceding the onset of menstruation	39	33.91
Part of the competition is negatively affected*	n = 85	
Perceive lacking strength/unable to lift substantial amounts of weight	25	29.41
Experienced less coordinated or clumsier	12	14.12
Tired more easily/have less endurance	65	76.47
Can't concentrate on the instructions or tactics given by the coach during the match	27	31.76
Experience a lack of swiftness in activities that require rapidity	7	8.24
There exists a disparity in my energy levels	55	64.71
Worried that there will be blood stains on clothes/uniform	35	41.18
Changing exercise during the menstrual cycle	n = 115	
No, neither I nor my coach will	66	53.79
Yes, I'm disposed	25	21.74
Yes, the coach and I both plan it	24	20.87

* Responses are allowed more than one and can add more than 100%

exercise and competition. However, only twenty-five athletes were willing to alter their exercise during the menstrual cycle, and twenty-four athletes intended to change their schedules with their coaches (Table 2).

Discussing menstruation of student-athletes

The majority of the 115 respondents (53.91 %) claimed they exclusively discuss menstruation with female coaches/managers (59.68 %). A minority of female student-athletes (40.32 %) did not address menstruation with their coach or any senior because they did not feel the need to do so (64.15 %) since their performance was unaffected. Also, three athletes said there was no easy or discreet method to connect with their coaches, and two believed they could not assist. Nevertheless, a considerable proportion of athletes (63.48 %) did not discuss their periods with medical personnel (Table 3).

Training participation group during menstrual cycle

The differences in exercise involvement among female student-athletes during their period are presented in Table 4.

Table 3. Discussion pertaining to the menstrual cycle

Discussing menstrual period	n	%
Discuss with the coach or anyone senior on the team about menstruation		
Yes	62	53.91
Not	53	46.09
With whom do you talk about menstruation	n = 62	
I will inform my coach/trainer/manager	25	40.32
Only a female coach/trainers/managers	37	59.68
Why not discuss your period with your coach?*	n = 53	
Embarrassed	12	22.64
Disgrace because they are male	17	32.08
Do not believe they will comprehend	5	9.43
Because they were males, I didn't believe they would comprehend	27	50.94
As the performance was unaffected, there was no need to inform the coach	34	64.15
Consider that they won't care	23	43.40
Thought they wouldn't care because they were boys	21	39.62
There is no easy or secret method to communicate with them	3	5.66
It is uncontrollable, so we must simply adapt	7	13.21
It is irrelevant to them	9	16.98
Believe they are unable to assist	2	3.77
Consult a medical practitioner regarding your period	n = 115	
Yes	42	36.52
Not	73	63.48

* Several responses are acceptable and can contribute over 100%

Due to the non-normality of the data regarding exercise time per day and exercise frequency per week, the Wilcoxon rank-sum (Mann-Whitney) test was utilized. On the basis of exercise participation, specifically the frequency of exercise per week, there were significant differences between the sample groups ($p = 0.011$).

Table 4. Differences in the training participation group of female student-athletes during menstruation

Indicator	Exercise participation		p-value
	Always	Sometimes	
Exercise duration per day (hours/day)	2.18 ± 0.38	2.02 ± 0.44	0.063
Exercise frequency per week (day/week)	4.31 ± 1.26	3.71 ± 0.92	0.011*

Discussion

Menstruation is particularly significant to observe due to the variations of the four primary female sex hormones: estrogen, progesterone, follicle-stimulating hormone, and luteinizing hormone during the period (Maged et al., 2017; Romero-Moraleda et al., 2019). This sex hormone is one of the determinative factors of biological sex (Kinsley, Bardi, Neigh, & Lambert, 2016), which distinguishes between sexes (Elliot-Sale et al., 2020). Furthermore, Meignié et al. (2021) also conveys that more longitudinal and prospective research is urgently necessary to investigate the influence of menstruation on women's physical performance to facilitate training guidance and individualization programs for female athletes. This present study aimed to investigate athletes' self-reported health concerns and sports performance during the menstrual cycle, both in training and competition, along with the willingness of the athletes to talk over pertinent to their menstrual cycles.

The complex interaction of hormones during the menstrual cycle has the potential to exert influence on several metabolic, cardiovascular, and pulmonary parameters (Yapıcı-Öksüzöğlu & Egesoy, 2021). Menstrual cycle disorders frequently experience among female athletes (Fernanda et al., 2021). This makes athletes use hormonal contraception more frequently, especially oral contraceptives, to reduce menstrual symptoms such as bloating and cramping, as well as to control the incidence of bleeding in preparing for the competition (Cheng et al., 2021). Our study shows that most athletes do not use drugs to prevent or delay menstruation, despite the fact that most feel pain during menstruation. In contrast to the data reported by Martin et al. (2018), which indicated that 68 % of athletes preferred oral contraceptive pills as their first choice of hormonal contraception, establishing this method as the most prevalent. Nevertheless, it is essential to acknowledge that the utilization of oral contraceptives may lead to a reduction in bone mineral density when compared to individuals who do not use such contraceptives, particularly among teenagers and young females (Goshtasebi et al., 2019).

Moreover, the findings of our inquiry underscore that a significant proportion of athletes encounter diverse health issues, including but not limited to lumbar discomfort, heightened susceptibility to fatigue, mood swings, cephalgia, and a wide range of health complications. However, the most dominant health problem is abdominal pain/pain in the low-

er abdomen. This is consistent with the findings of Randell et al. (2021), which indicate that female football players experience sport performance-impairing side effects, including nausea, headaches, and stomach pains during their menstrual cycle. Armento et al. (2021) as well consistently disclosed that menstruation experienced by athletes causes fatigue, back pain, and reduced energy (63 %), and 45 % of elite female athletes in long-distance events experience bone health problems. Furthermore, a research investigation conducted by Bruinvels et al. (2016) also revealed that more than seventy percent of elite athletes encountered detrimental side effects linked to the menstrual cycle, with adverse effects comprising twenty-four discrete symptoms that varied in duration, severity, and occurrence among the participants. Senatore et al. (2019) also reported that the menstruation exerts a substantial impact on the activities undertaken by athletes, encompassing both physical and mental dimensions.

Athletes' hormonal profiles are essential for developing accurate individual profiles that can be associated with their performance (e.g., strength and plyometric competence), injuries, and exercise response (Julian & Sargent, 2020). A significant proportion of Australian female athletes, Olympians, and/or Paralympians preparing for the Tokyo Olympics and/or Paralympics admitted that menstruation impacted their performance during exercise (sixty-five percent) and competition (fifty-eight percent) respectively (McNamara, Harris, & Minahan, 2022), particularly during the early stages of the follicular and late luteal phase (Righi & Barroso, 2022). Our present study also disclosed that most collegiate female athletes consider their menstrual cycle to exert an adverse impact both during training and competition, which causes them to tire more easily, have less endurance, and reduce their speed during physical activity. This is also supported by research conducted by Read et al. (2022) on elite female football players from two English Women's Super League (WSL) clubs, who revealed that all participants (100 %) reported perceiving a negative impact on their performance due to their menstrual cycle, and more than half of the players (53 %) reported experiencing decreased appetite and sleep quality prior to engaging in sports activities during menstruation. Meanwhile, a study conducted by Solli et al. (2020) unveiled that a significant proportion of competitive endurance athletes engaged in biathlon or cross-country skiing saw either improved (42 %) or diminished (49 %) performance during their period.

The coach is responsible not only for enhancing athlete performance by evaluating physical, mental, and strategic training but also for various physiological, health, and emotional issues in each athlete, such as the menstrual cycle, which is unavoidable for female athletes. Menstruation is frequently perceived as a biological process related to culture and social meaning and is often viewed negatively (Botello-Hermosa & Casado-Mejia, 2015). The results of our study show that more than fifty percent of respondents chose to discuss the menstrual cycle with coaches. Still, only female coaches/managers and several other athletes chose not to discuss it with their male coaches/managers because of embarrassment. They assumed that male trainers did not understand menstruation. This is consistent with what was revealed by Findlay et al. (2020) that some elite athletes are reluctant to tell their menstrual cycles to coaches or male staff on their team due to awkwardness, embarrassment, and

gender differences, as well as the athletes believe that their coaches cannot assist.

The results of the thematic analysis conducted by Martina et al. (2021) expressed that knowledge (e.g., ignorance or perceptions of inadequate knowledge levels), interpersonal (e.g., the incorrect presumption about the coach/athletes and social discomfort), and structural, e.g., differences in collective perceptions that affect coaches/athletes disproportionately) are the three primary reasons why female athletes do not disclose their menstrual cycles to coaches. Bergström et al. (2023) also conformable that the barrier between female athletes and male coaches in discussing menstruation is the incorrect assumption and prejudice that coaches do not want to be bothered with their menstrual cycle issues or cannot comprehend them. Consequently, despite having a greater understanding of these issues, coaches interpret female athletes' reticence as a lack of desire or need to discuss their menstrual issues. Kristiansen et al. (2012) explained that athletes' perceptions of coach knowledge could create a communication barrier between athletes and coaches and lead to poorly designed training programs, which is likely to significantly impact their sporting performance (de Haan & Norman, 2020).

Moreover, there was a significant difference in training frequency per week (week/day) among female collegiate student-athletes to their menstrual period, which is another noteworthy finding from our present study that should be highlighted. Our result was consistent with Ergin and Kartal (2020), who explained that Volleyball players who competed in the Turkish Volleyball Sultans' League conveyed that their menstrual cycle occasionally interferes with their participation both in training (46.2%) and competition (99.2%). Twenty percent of participants in the study by Adam et al. (2022) reported skipping training or competition due to unbearable pain during their menstrual cycle. Experiencing pain during the menstrual period is a physiological response to the underlying health issue, mainly due to hormonal fluctuations. Hence, athletes may not consistently be able to engage either in training or competition designed to improve their skills and talents. Concerning this, it is essential to consider educational interventions for both athletes and coaches (Brown & Knight, 2022), including management strategies for training and competition that consider the athlete's menstrual cycle (Brown, Knight, & Forrest (née Whyte), 2021; Statham, 2020).

This present study was limited to female student-athletes perspectives; future researchers are encouraged to discover more about the viewpoints of coaches and club managers regarding the health issues experienced by athletes and their performance during menstruation, including their coping strategies. Follow-up focus group discussions could also be conducted between athletes, coaches, and club managers to investigate these issues further. Additionally, information regarding coaches' along with the club managers' perceptions of menstruation must be explored further to determine whether they genuinely do not comprehend the effects of menstruation on performance due to a lack of understanding or because club managers impose a championship goal for each athlete in achievement sports training.

Conclusions

The management of coaching male and female athletes has different levels of difficulty. The menstrual cycle is one

factor that contributes to female athletes' more complex coaching management than male athletes. The findings from our research emphasize that female collegiate-student athletes experience various health issues during menstruation. Our study also found a communication gap between athletes and coaches, notably the athletes' reluctance to communicate and plan their training with their coaches while considering their menstrual cycle. Hence, athletes and coaches must be informed of the physical, psychological, and emotional health difficulties that can arise during menstruation. On the other hand, building awareness among athletes and coaches concerning the menstrual cycle's impact on athletes' health, well-being, and performance is another key to success that can be incorporated into a management strategy for sports achievement development for women. Coaches can encourage communication by asking athletes about their menstrual cycles and using smartphone/smartwatch apps to monitor information about their upcoming periods. Thus, athletes and coaches can work together to discuss and adjust training programs by considering the athlete's menstrual cycle, especially in the early follicular and the follicular or proliferative phase, which causes athletes tend to experience fatigue more quickly and experience excessive pain. Additionally, medical practitioners and sports nutritionists must be involved in athlete development initiatives programs to maximize athlete performance during training and competition.

Conflict of interest

There are no conflicts of interest to report.

References

- Fink, J. S. (2015). Female athletes, women's sport, and the sport media commercial complex: Have we really "come a long way, baby"? *Sport Management Review*, 18(3), 331-342. <https://doi.org/10.1016/j.smr.2014.05.001>
- Forsyth, J., & Roberts, C.-M. (2018). *Introduction to The Exercising Female: Science and Its Application*. In *The Exercising Female*. Routledge.
- International Olympic Committee. (2020). *Gender equality through time: At the Olympic Games*. Retrieved February 18, 2023, from <https://olympics.com/ioc/gender-equality/gender-equality-through-time>
- Mikkelsen, K., Stojanovska, L., Polenakovic, M., Bosevski, M., & Apostolopoulos, V. (2017). Exercise and mental health. *Maturitas*, 106, 48-56. <https://doi.org/10.1016/j.maturitas.2017.09.003>
- Lavie, C. J., Arena, R., Swift, D. L., Johannsen, N. M., Sui, X., Lee, D.-C., ... Blair, S. N. (2015). Exercise and the cardiovascular system: Clinical science and cardiovascular outcomes. *Circulation Research*, 117(2), 207-219. <https://doi.org/10.1161/CIRCRESAHA.117.305205>
- Harrison, C. L., Brown, W. J., Hayman, M., Moran, L. J., & Redman, L. M. (2016). The Role of Physical Activity in Preconception, Pregnancy and Postpartum Health. *Seminars in Reproductive Medicine*, 34(02), e28-e37. <https://doi.org/10.1055/s-0036-1583530>
- Orio, F., Muscogiuri, G., Ascione, A., Marciano, F., Volpe, A., La Sala, G., ... Palomba, S. (2013). Effects of physical exercise on the female reproductive system. *Minerva Endocrinologica*, 38(3), 305-319.
- Caudwell, P., Gibbons, C., Finlayson, G., Näslund, E., & Blundell, J. (2014). Exercise and Weight Loss: No Sex

- Differences in Body Weight Response to Exercise. *Exercise and Sport Sciences Reviews*, 42(3), 92-101. <https://doi.org/10.1249/JES.0000000000000019>
- Swift, D. L., Johannsen, N. M., Lavie, C. J., Earnest, C. P., & Church, T. S. (2014). The Role of Exercise and Physical Activity in Weight Loss and Maintenance. *Progress in Cardiovascular Diseases*, 56(4), 441-447. <https://doi.org/10.1016/j.pcad.2013.09.012>
- Holtzman, B., & Ackerman, K. E. (2021). Recommendations and Nutritional Considerations for Female Athletes: Health and Performance. *Sports Medicine*, 51(1), 43-57. <https://doi.org/10.1007/s40279-021-01508-8>
- Lebrun, C. M., Joyce, S. M., & Constantini, N. W. (2013). *Effects of Female Reproductive Hormones on Sports Performance*. In N. Constantini & A. C. Hackney (Eds.), *Endocrinology of Physical Activity and Sport: Second Edition* (pp. 281-322). Totowa, NJ: Humana Press. https://doi.org/10.1007/978-1-62703-314-5_16
- Mountjoy, M., Sundgot-Borgen, J., Burke, L., Carter, S., Constantini, N., Lebrun, C., ... Ljungqvist, A. (2014). The IOC consensus statement: Beyond the Female Athlete Triad—Relative Energy Deficiency in Sport (RED-S). *British Journal of Sports Medicine*, 48(7), 491-497. <https://doi.org/10.1136/bjsports-2014-093502>
- Ön, S., Diker, G., & Özkamçı, H. (2014). Effect Of Menstrual Cycle Anaerobic Power and Active Jumping Performance at Adolescent Volleyball Athletes. *E-Journal of New World Sciences Academy*, 9, 32-42. <https://doi.org/10.12739/NWSA.2014.9.2.2B0099>
- Julian, R., & Sargent, D. (2020). Periodisation: Tailoring training based on the menstrual cycle may work in theory but can they be used in practice? *Science and Medicine in Football*, 4(4), 253-254. <https://doi.org/10.1080/24733938.2020.1828615>
- Oosthuysen, T., & Bosch, A. N. (2010). The effect of the menstrual cycle on exercise metabolism: Implications for exercise performance in eumenorrhoeic women. *Sports Medicine (Auckland, N.Z.)*, 40(3), 207-227. <https://doi.org/10.2165/11317090-000000000-00000>
- Constantini, N. W., Dubnov, G., & Lebrun, C. M. (2005). The menstrual cycle and sport performance. *Clinics in Sports Medicine*, 24(2), e51-82, XIII-XIV. <https://doi.org/10.1016/j.csm.2005.01.003>
- Loveless, M. B. (2017). Female athlete triad. *Current Opinion in Obstetrics and Gynecology*, 29(5), 301-305. <https://doi.org/10.1097/GCO.0000000000000396>
- Meczekalski, B., Katulski, K., Czyzyk, A., Podfigurna-Stopa, A., & Maciejewska-Jeske, M. (2014). Functional hypothalamic amenorrhea and its influence on women's health. *Journal of Endocrinological Investigation*, 37(11), 1049-1056. <https://doi.org/10.1007/s40618-014-0169-3>
- Findlay, R. J., Macrae, E. H. R., Whyte, I. Y., Easton, C., & Forrest Née Whyte, L. J. (2020). How the menstrual cycle and menstruation affect sporting performance: Experiences and perceptions of elite female rugby players. *British Journal of Sports Medicine*, 54(18), 1108-1113. <https://doi.org/10.1136/bjsports-2019-101486>
- Parker, M., Sneddon, A., & Arbon, P. (2010). The menstrual disorder of teenagers (MDOT) study: Determining typical menstrual patterns and menstrual disturbance in a large population-based study of Australian teenagers. *BJOG: An International Journal of Obstetrics & Gynaecology*, 117(2), 185-192. <https://doi.org/10.1111/j.1471-0528.2009.02407.x>
- Subasinghe, A. K., Hapoo, L., Jayasinghe, Y. L., Garland, S. M., Gorelik, A., & Wark, J. D. (2016). Prevalence and severity of dysmenorrhoea, and management options reported by young Australian women. *Australian Family Physician*, 45(11), 829-834.
- Wodarska, M., Witkoś, J., Drosdzol-Cop, A., Dąbrowska, J., Dąbrowska-Galas, M., Hartman, M., ... Skrzypulec-Plinta, V. (2013). Menstrual cycle disorders in female volleyball players. *Journal of Obstetrics and Gynaecology*, 33(5), 484-488. <https://doi.org/10.3109/01443615.2013.790885>
- Prado Seoane, Á. (2013). Influencia del ciclo menstrual en la flexibilidad en natación sincronizada. *Agon*, 3(2), 53-59.
- Ansdell, P., Brownstein, C. G., Škarabot, J., Hicks, K. M., Simoes, D. C. M., Thomas, K., ... Goodall, S. (2019). Menstrual cycle-associated modulations in neuromuscular function and fatigability of the knee extensors in eumenorrhoeic women. *Journal of Applied Physiology*, 126(6), 1701-1712. <https://doi.org/10.1152/jappphysiol.01041.2018>
- Bruinvels, G., Burden, R. J., McGregor, A. J., Ackerman, K. E., Dooley, M., Richards, T., & Pedlar, C. (2017). Sport, exercise and the menstrual cycle: Where is the research? *British Journal of Sports Medicine*, 51(6), 487-488. <https://doi.org/10.1136/bjsports-2016-096279>
- Costello, J. T., Bieuzen, F., & Bleakley, C. M. (2014). Where are all the female participants in Sports and Exercise Medicine research? *European Journal of Sport Science*, 14(8), 847-851. <https://doi.org/10.1080/17461391.2014.911354>
- Cowley, E. S., Olenick, A. A., McNulty, K. L., & Ross, E. Z. (2021). "Invisible Sportswomen": The Sex Data Gap in Sport and Exercise Science Research. *Women in Sport and Physical Activity Journal*, 29(2), 146-151. <https://doi.org/10.1123/wspaj.2021-0028>
- Carmichael, M. A., Thomson, R. L., Moran, L. J., & Wycherley, T. P. (2021). The Impact of Menstrual Cycle Phase on Athletes' Performance: A Narrative Review. *International Journal of Environmental Research and Public Health*, 18(4), 1667. <https://doi.org/10.3390/ijerph18041667>
- Armour, M., Parry, K. A., Steel, K., & Smith, C. A. (2020). Australian female athlete perceptions of the challenges associated with training and competing when menstrual symptoms are present. *International Journal of Sports Science & Coaching*, 15(3), 316-323. <https://doi.org/10.1177/1747954120916073>
- Maged, A. M., Salah, E., Kamel, A. M., Hussein, A. M., Saad, H., Meshaal, H., & Kamal, W. M. (2017). Effect of oral contraceptives on balance in women: A randomized controlled trial. *Taiwanese Journal of Obstetrics & Gynecology*, 56(4), 463-466. <https://doi.org/10.1016/j.tjog.2017.02.003>
- Romero-Moraleda, B., Coso, J. D., Gutiérrez-Hellín, J., Ruiz-Moreno, C., Grgic, J., & Lara, B. (2019). The Influence of the Menstrual Cycle on Muscle Strength and Power Performance. *Journal of Human Kinetics*, 68, 123-133. <https://doi.org/10.2478/hukin-2019-0061>
- Kinsley, C., Bardi, M., Neigh, G. N., & Lambert, K. (2016). *Chapter 2—Chromosomal and Endocrinological Origins of Sex*. In G. N. Neigh & M. M. Mitzelfelt (Eds.), *Sex Differences in Physiology* (pp. 5–15). Boston: Academic Press. <https://doi.org/10.1016/B978-0-12-802388-4.00002-1>
- Elliott-Sale, K. J., McNulty, K. L., Ansdell, P., Goodall, S., Hicks, K. M., Thomas, K., ... Dolan, E. (2020). The Effects

- of Oral Contraceptives on Exercise Performance in Women: A Systematic Review and Meta-analysis. *Sports Medicine (Auckland, N.Z.)*, 50(10), 1785-1812. <https://doi.org/10.1007/s40279-020-01317-5>
- Meignié, A., Duclos, M., Carling, C., Orhant, E., Provost, P., Toussaint, J.-F., & Antero, J. (2021). The Effects of Menstrual Cycle Phase on Elite Athlete Performance: A Critical and Systematic Review. *Frontiers in Physiology*, 12. <https://doi.org/10.3389/fphys.2021.654585>
- Yapıcı-Öksüzöğlü, A., & Egesoy, H. (2021). The effect of menstrual cycle on anaerobic power and jumping performance. *Pedagogy of Physical Culture and Sports*, 25(6), 367-372. <https://doi.org/10.15561/26649837.2021.0605>
- Fernanda, C., Gifari, N., Mulyani, E. Y., Nuzrina, R., & Ronitawati, P. (2021). Hubungan Asupan, Status Gizi, Aktivitas Fisik, Tingkat Stres dan Siklus Menstruasi Atlet Bulutangkis. *Sport and Nutrition Journal*, 3(1), 1-14. <https://doi.org/10.15294/spnj.v3i1.41133>
- Cheng, J., Santiago, K. A., Abutalib, Z., Temme, K. E., Hulme, A., Goolsby, M. A., ... Casey, E. K. (2021). Menstrual Irregularity, Hormonal Contraceptive Use, and Bone Stress Injuries in Collegiate Female Athletes in the United States. *PM & R: The Journal of Injury, Function, and Rehabilitation*, 13(11), 1207-1215. <https://doi.org/10.1002/pmrj.12539>
- Martin, D., Sale, C., Cooper, S. B., & Elliott-Sale, K. J. (2018). Period Prevalence and Perceived Side Effects of Hormonal Contraceptive Use and the Menstrual Cycle in Elite Athletes. *International Journal of Sports Physiology and Performance*, 13(7), 926-932. <https://doi.org/10.1123/ijsp.2017-0330>
- Goshtasebi, A., Subotic Brajic, T., Scholes, D., Beres Lederer Goldberg, T., Berenson, A., & Prior, J. C. (2019). Adolescent use of combined hormonal contraception and peak bone mineral density accrual: A meta-analysis of international prospective controlled studies. *Clinical Endocrinology*, 90(4), 517-524. <https://doi.org/10.1111/cen.13932>
- Randell, R. K., Clifford, T., Drust, B., Moss, S. L., Unnithan, V. B., De Ste Croix, M. B. A., ... Rollo, I. (2021). Physiological Characteristics of Female Soccer Players and Health and Performance Considerations: A Narrative Review. *Sports Medicine (Auckland, N.Z.)*, 51(7), 1377-1399. <https://doi.org/10.1007/s40279-021-01458-1>
- Armento, A., VanBaak, K., Seehusen, C. N., Sweeney, E. A., Wilson, J. C., & Howell, D. R. (2021). Presence and Perceptions of Menstrual Dysfunction and Associated Quality of Life Measures Among High School Female Athletes. *Journal of Athletic Training*, 56(10), 1094-1099. <https://doi.org/10.4085/624-20>
- Bruinvels, Georgie, Burden, R., Brown, N., Richards, T., & Pedlar, C. (2016). The Prevalence and Impact of Heavy Menstrual Bleeding (Menorrhagia) in Elite and Non-Elite Athletes. *PloS One*, 11(2), e0149881. <https://doi.org/10.1371/journal.pone.0149881>
- Senatore, B., Pisapia, F., & Domenico, F. D. (2019). Menstrual cycle disorders in rhythmic gymnastics athletes. *Journal of Physical Education and Sport*, 19(Supplement issue 5). <https://doi.org/10.7752/jpes.2019.s5299>
- McNamara, A., Harris, R., & Minahan, C. (2022). 'That time of the month' ... for the biggest event of your career! Perception of menstrual cycle on performance of Australian athletes training for the 2020 Olympic and Paralympic Games. *BMJ Open Sport & Exercise Medicine*, 8(2), e001300. <https://doi.org/10.1136/bmjsem-2021-001300>
- Righi, I., & Barroso, R. (2022). Do Recreationally-Trained Women of Different Ages Perceive Symptoms of the Menstrual Cycle and Adjust Their Training According to Phases? *International Journal of Environmental Research and Public Health*, 19(21), 13841. <https://doi.org/10.3390/ijerph192113841>
- Read, P., Mehta, R., Rosenbloom, C., Jobson, E., & Okholm Kryger, K. (2022). Elite female football players' perception of the impact of their menstrual cycle stages on their football performance. A semi-structured interview-based study. *Science & Medicine in Football*, 6(5), 616-625. <https://doi.org/10.1080/24733938.2021.2020330>
- Solli, G. S., Sandbakk, S. B., Noordhof, D. A., Ihalainen, J. K., & Sandbakk, Ø. (2020). Changes in Self-Reported Physical Fitness, Performance, and Side Effects Across the Phases of the Menstrual Cycle Among Competitive Endurance Athletes. *International Journal of Sports Physiology and Performance*, 1-10. <https://doi.org/10.1123/ijsp.2019-0616>
- Botello-Hermosa, A., & Casado-Mejia, R. (2015). Fears and concerns related to menstruation: A qualitative study from the perspective of gender. *Texto & Contexto - Enfermagem*, 24, 13-21. <https://doi.org/10.1590/0104-07072015000260014>
- Martina, D., Lin, C.-P., Kristanti, M. S., Bramer, W. M., Mori, M., Korfage, I. J., Van Der Heide, A., Van Der Rijt, C. C. D., & Rietjens, J. A. C. (2021). Advance Care Planning in Asia: A Systematic Narrative Review of Healthcare Professionals' Knowledge, Attitude, and Experience. *Journal of the American Medical Directors Association*, 22(2), 349.e1-349.e28. <https://doi.org/10.1016/j.jamda.2020.12.018>
- Bergström, M., Rosvold, M., & Sæther, S. A. (2023). "I hardly have a problem [...] I have my period quite rarely too": Female football players' and their coaches' perceptions of barriers to communication on menstrual cycle. *Frontiers in Sports and Active Living*, 5. <https://doi.org/10.3389/fspor.2023.1127207>
- Kristiansen, E., Tomten, S. E., Hanstad, D. V., & Roberts, G. C. (2012). Coaching communication issues with elite female athletes: Two Norwegian case studies. *Scandinavian Journal of Medicine & Science in Sports*, 22(6), e156-167. <https://doi.org/10.1111/j.1600-0838.2012.01521.x>
- de Haan, D., & Norman, L. (2020). Mind the gap: The presence of capital and power in the female athlete-male -coach relationship within elite rowing. *Sports Coaching Review*, 9(1), 95-118. <https://doi.org/10.1080/21640629.2019.1567160>
- Ergin, E., & Kartal, A. (2020). Menstrual Cycle and Sporting Performance Perceptions of Elite Volleyball Players. *International Journal of Applied Exercise Physiology*, 9(10), 57-64. <https://doi.org/10.26655/IJAEP.2020.10.1>
- Adam, M. E. K., Bristow, A., Neely, K. C., & Erlandson, M. C. (2022). Do women athletes' experiences of menstrual function and dysfunction vary across competition levels? A mixed methods exploration. *Psychology of Sport and Exercise*, 63, 102270. <https://doi.org/10.1016/j.psychsport.2022.102270>

Brown, N., & Knight, C. J. (2022). Understanding female coaches' and practitioners' experience and support provision in relation to the menstrual cycle. *International Journal of Sports Science & Coaching*, 17(2), 235-243. <https://doi.org/10.1177/17479541211058579>

Brown, N., Knight, C. J., & Forrest (née Whyte), L. J. (2021). Elite female athletes' experiences and perceptions of the menstrual cycle on training and sport performance.

Scandinavian Journal of Medicine & Science in Sports, 31(1), 52-69. <https://doi.org/10.1111/sms.13818>

Statham, G. (2020). *Understanding the effects of the menstrual cycle on training and performance in elite athletes: A preliminary study*. In B. L. Parkin (Ed.), *Progress in Brain Research* (pp. 25-58). Elsevier. <https://doi.org/10.1016/bs.pbr.2020.05.028>

Визначення впливу менструального циклу на студенток-спортсменок: Самооцінка проблем, пов'язаних із станом здоров'я, спортивними показниками та готовністю обговорювати питання щодо менструації

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

Реферат. Стаття: 10 с., 4 табл., 1 рис., 57 джерел.

Історія питання. Комплексне розуміння менструального циклу, пов'язаних з цим фізіологічним процесом проблем зі здоров'ям і подальшого впливу на спортивну результативність сприятимуть формулюванню обґрунтованих та індивідуальних стратегій тренувань і участі у змагальних видах спорту. У свою чергу, такі знання можуть зменшити ймовірність виникнення травм, підтримати психологічне благополуччя і, зрештою, підвищити продуктивність спортсменок.

Мета дослідження. Метою дослідження було вивчити ставлення студенток-спортсменок до проблем, пов'язаних із станом здоров'я та спортивних результатів під час менструального циклу, як з точки зору тренувань, так і змагань, а також готовність спортсменок обговорювати питання, що стосуються їхнього менструального циклу.

Матеріали та методи. У нашому дослідженні взяли участь 115 студенток-спортсменок, які займаються індивідуальними/командними видами спорту на суші (n = 95) та комбінованими видами спорту на суші/воді (n = 20). З метою збору даних для цього перехресного дослідження було використано опитувальник, який заповнювали самі учасниці. Було проведено описовий аналіз, результати якого представлено у вигляді частоти та відсотків, після чого було застосовано критерій рангових сум Вілкоксона (критерій Манна-Уїтні) для аналізу середніх відмінностей між групами учасниць тренувань під час менструації.

Результати. Загалом, усі спортсменки стикалися з кількома проблемами зі здоров'ям, найпоширенішими з яких були біль у животі та нижній частині спини. Крім того, майже всі учасниці дослідження (95,33%) відчували біль у перший день менструального циклу. Менструація також впливає на показники результативності спортсменок під час фізичних вправ (70,43%) та змагань (73,91%), викликаючи у більшості з них підвищену втомлюваність та зниження рівня витривалості. Також спостерігається суттєва різниця між контекстом тренувального процесу та кількістю сеансів щотижневих фізичних вправ (0,011) під час менструального циклу.

Висновки. Менструація суттєво впливає на стан здоров'я та продуктивність спортсменок як під час тренувань, так і під час спортивних змагань. Вкрай важливо, щоб тренери та спортсменки мали комплексне розуміння механізму менструального циклу з метою ефективного розв'язання цієї проблеми. Крім того, залучення медичних працівників та спортивних дієтологів до процесу регулювання менструального циклу є ще однією стратегією щодо підвищення результативності спортсменок.

Ключові слова: період, проблеми зі здоров'ям, фолікулярна фаза, спортсменки, фізичні вправи, змагання.

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Karate Game: Using a Playful and Participatory Approach to Enhancing Children's Social and Motor Perception during the Developmental Age

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Abstract

Objectives. The study aimed to evaluate the effects of sport-specific educational proposals in school-age sports, currently used in planning of sports activities, such as game-based karate training, on social interactions and improving perceptions of one's motor skills.

Materials and methods. The sample consisted of 34 children from the Comprehensive Institute "Matilde Serao" in Ortona, Chieti, attending the third classes of the Primary School, in the school year 2023/2024. The method used was based on the Karate Sport Game protocols in conjunction with the dissemination of the ethical principles inherent to the martial arts. A questionnaire was developed for the purpose of assessing the learners' levels of satisfaction, as well as the perceptions they had about themselves and in relation to others during this training intervention.

Results. In the post-implementation evaluation of the educational proposals' results, it was shown that 94.1 % of participants had a positive experience engaging in the Game-Karate activities, 82.3 % reported feeling significantly supported by the Instructors during the project, and 94.1% were very satisfied with the activities. The application of the Chi-Square test revealed two significant relationships with respect to the concept of opportunity for interaction with all peers. The first pertained to the participants' overall satisfaction with the karate instructional project ($p = 0.006$), while the second concerned the concept of improving teamwork ($p = 0.006$).

Conclusion. The findings indicate that Karate Game had a beneficial impact on the participants' emotional sphere, involvement, perceived improvement in motor skills, and group dynamics. In addition, the significant relationships found underscore the importance of social interaction and collaboration in the context of physical activity. These results suggest that playful and participatory approach to the training process in Karate classes can be a valuable resource for the comprehensive development of children's personality and motor skills during the developmental age.

Keywords: martial arts, personality, motor skills, innovative methodologies, perceptions, relationships.

Introduction

Motor development, plays a key role from the earliest years of a person's life, as it forms the foundation on which the physical, cognitive and social skills needed to meet challenges

and adapt effectively to the world around them are built. It is important to point out that during the 8-10 age group, children go through a critical stage in motor development, characterized by significant progress in fundamental motor skills (Raiola et al, 2022). This period is crucial for the formation of basic motor skills that will influence their physical well-being and participation in physical activities throughout their lives (D'elia et al, 2023). According to developmental psychologist Robert Kail, during this period,

children become more adept at coordinating complex movements and controlling their balance (Kail, 2000). In addition, during school age children show significant improvements in fine motor skills, with greater speed and accuracy in hand-eye coordination tasks (Piek et al, 1999). Physical improvements must go hand in hand with age-appropriate psychological development (Di Domenico et al, 2023). The main components certainly include optimal psychophysical balance, defined as a long-term goal (Raiola et al, 2023). Positive signs can also be observed in students with socialization problems through the adoption of sports interventions. Such signs can be easily verified during activities (D'Isanto et al, 2022). These include the martial arts, which, with their disciplined approach and inherent values of respect, self-discipline and perseverance, offer fertile ground in the motor and psychological development of practitioners (Altavilla et al, 2022). Karate, in particular, combines precise and coordinated movements with a philosophy of personal growth and self-improvement, promoting the idea of an environment in which each individual can grow and improve. Through Karate, motor skills can be acquired, skills can be developed, and new skills can be introduced into learners, which can be used to enrich overall intelligence in order to put them to use in all activities throughout the developmental years. Numerous studies have highlighted the effectiveness of Karate as a means of improving children's physical and mental health (Chaabène et al, 2017). These researches have shown that regular practice of Karate leads to significant improvements in cardiorespiratory endurance, muscular strength, and flexibility in children (Altavilla et al, 2022). In addition, balance control and motor coordination, fundamental aspects of physical development during childhood, are promoted with this discipline. What makes this sport an exceptional educational tool is its planetary cultural conception, aimed at the improvement of the person and not a part of the person, or a particular type of individual. Children can find in the Master a reassuring point of reference that gives them the tools to relate to others correctly or to become aware of their own potential. In order to make the practice of sports, of a martial discipline, more rewarding, it is possible to adapt it, creating a work environment that offers more stimulation to learners and that proposes personal and group challenges in a fun context. This is where playful activity comes in. Play is an instinctive, comprehensive and fun activity. The word play, before bringing physical components into play, activates the cognitive aspect and problem solving skills in the playful and relational environment (Di Domenico et al, 2023). The play component in Karate is still underestimated, but when applied it finds significant benefits in practitioners' learning at the psychophysical level. There is still a tendency to adopt traditional, repetitive and often boring approaches that are not in line with the expectations of modern generations and fail to produce optimal results. These young people are accustomed to the interactivity of new technologies and to receiving immediate feedback tailored to their specific needs (D'elia et al, 2021). In the context of teaching Karate to children, a significant impairment of motor skills and abilities emerges, as well as a negative impact on their psychological and relational sphere, aspects that need to be resolved from childhood (D'Isanto et al, 2022). In addition, there is limited use of alternative teaching methodologies

compared to the traditional approach, and play certainly helps to improve movement components by providing a suitable motivational context.

Purpose of the research – evaluate how sport-specific educational proposals in school-age sports, currently used in planning sports activities such as game-karate, influence perception in social interactions, while also improving perception of one's motor skills (Raiola et al., 2023).

Materials and Methods

Study Participants

The sample of this study includes 34 children of the Istituto Comprensivo "Matilde Serao" in Ortona, in the province of Chieti, attending the third grade of the Primary School in the school year 2023/2024. The group of learners is heterogeneous, in gender, socioeconomic status of origin and physical-athletic condition. The learners have had prior experience in various sports, but few have previously practiced Karate.

Study Organization

The participants underwent 40 structured sessions of one hour each of Karate Game, carried out over a period of 5 months, using Karate sports game methodologies, in accordance with FIJLKAM guidelines. The courses are performed on a square of rubber mats preferably 10x10 meters, divided into 5 lanes of 2 meters wide. There must be guaranteed 1 meter of space for turning to the next lane. In each course the element is repeated if the athlete does not perform the exercise as prescribed. The training sessions are designed to improve motor patterns, motor skills and abilities by promoting martial arts values. All activities will have a bottom up approach from the bottom up rather than top down from the top down. With this methodology, the learner will be placed at the forefront in self-determination during the activities, highlighting their strengths and reinforcing their weaknesses; the teacher's role will be to guide, push and monitor the activities. The training protocols of each lesson are structured in an activation phase, in the study of basic Karate techniques, providing specific workouts that make the learners acquire the physical characteristics required for the sport, the playful part with the courses, a part dedicated to fighting skills and finally, the final cooldown phase. This is briefly described in Table 1.

These exercises within the educational proposal are adapted according to the experience level and specific needs of the participants, ensuring that a balance between challenge and fun is maintained during the Karate Game sessions. A questionnaire was developed and submitted to the participants at the end of the educational intervention, consisting of 8 questions, with 4 structured responses, all represented in Table 2.

Statistical analysis

Following the responses to the questionnaire from the sample considered, a descriptive statistical analysis was carried out; only then were the data analyzed by performing a Chi Framework analysis to understand whether or not there were significant relationships between the qualitative variables, using the statistical software JASP.

Table 1. Educational proposal of lessons

Neuro-muscular activation	Dynamic warm-up to prepare muscles and improve flexibility
Techniques basic karate	Introduction of kicks, punches and parries
Reaction and agility drills	Exercises that improve learners' agility and responsiveness, including footwork, circuit exercises involving quick movements, change of directions, and exercises that require fast reaction times
Body coordination, stability and balancing exercises	Aimed at improving eye-hand coordination, balance and stability. Included are exercises with moving targets, precision drills and exercises involving the use of equipment such as medicine balls or stability cushions.
Specific playful-motor exercises	Adoption of games calibrated to indirectly improve motor skills and abilities specific to karate such as capture flags, poison ball, 1 2 3 star. FIJILKAM Protocol: Combined Game Sport.
Exercises for learning combat	Application of Karate techniques towards moving targets, balloon bags, in a controlled environment, taking advantage of all the technical-tactical peculiarities that the sport requires.
Cooldown	Each training session is concluded with a cooldown and stretching exercises to relax the muscles and reduce the risk of injury.

Table 2. Questionnaire

Questions	Answer 1	Answer 2	Answer 3	Answer 4
1) How much fun did you have participating in Karate Sports Game activities?	Very	Somewhat	A little	Not at all
2) Did you feel that through play your motor skills improved?	Very	Somewhat	A little	Not at all
3) Did you have the opportunity to interact with all your teammates?	Very	Somewhat	A little	Not at all
4) Did you feel your teamwork improved during the project?	Very	Somewhat	A little	Not at all
5) Were the instructions for the game activity clear and easy to follow?	Very	Somewhat	A little	Not at all
6) Did you feel supported by the Instructors during the project?	Very	Somewhat	A little	Not at all
7) Do you feel that the project positively promoted Karate values (respect, integrity, honor)?	Very	Somewhat	A little	Not at all
8) What is your overall level of satisfaction with the Karate instructional project?	Very	Somewhat	A little	Not at all

Table 3. Results of questionnaire responses

Questionnaire	Very	Somewhat	A little	Not at all
1) How much fun did you have participating in Karate Sports Game activities?				
Frequency	25.0	7.0	2.0	0
Percentage	73.4	20.7	5.9	0
2) Did you feel that through play your motor skills improved?				
Frequency	17.0	13.0	4.0	0
Percentage	49.9	38.3	11.8	0
3) Did you have the opportunity to interact with all your teammates?				
Frequency	32.0	2.0	0	0
Percentage	94.1	5.9	0	0
4) Did you feel your teamwork improved during the project?				
Frequency	32.0	2.0	0	0
Percentage	94.1	5.9	0	0
5) Were the instructions for the game activity clear and easy to follow?				
Frequency	30.0	4.0	0	0
Percentage	88.3	11.7	0	0
6) Did you feel supported by the Instructors during the project?				
Frequency	34.0	0	0	0
Percentage	100.0	0	0	0
7) Do you feel that the project positively promoted Karate values (respect, integrity, honor)?				
Frequency	31.0	3.0	0	0
Percentage	91.1	8.9	0	0
8) What is your overall level of satisfaction with the Karate instructional project?				
Frequency	32.0	2.0	0	0
Percentage	94.1	5.9	0	0

Results

After the questionnaire was administered, the results shown in Table 3 were found.

The results showed that, to question 1 'How much fun did you have participating in Karate Sports Game activities?' 94.1 % answered very, 5.9 % answered somewhat, none answered a little, and none answered not at all. To question 2 'Did you feel that through play your motor skills improved?' 49.9 % answered very, 38.3 % somewhat, 11.8 % a little. To question 3 'Did you have the opportunity to interact with all of your teammates?' 94.1 % answered very, 5.9 % somewhat. To question 4 'Did you feel your teamwork improved during the project?' 94.1 % answered very, 5.9 % somewhat, none answered a little or not at all. To question 5 'Were the instructions for the game activity clear and easy to follow?' 88.3 % answered very, 11.7 % somewhat, none a little or not at all. To question 6 'Did you feel supported by the Instructors during the project?' 100 % answered very. To question 7 'Do you feel that the project positively promoted Karate values (respect, integrity, honor)?' 91.1 % answered very, 8.9 % somewhat, none a little or not at all. To question 8 'What is your overall level of satisfaction with the Karate instructional project?' 94.1 % answered very, 5.9 % somewhat, none a little and not at all. Following the Chi-Square analysis, two significant relationships were found among the qualitative variables. The first relationship relates to question 4 'Did you feel your teamwork improved during the project?' and question 3 'Did you have the opportunity to interact with all your teammates?' where a $p=0.006$ was found. This is shown in the Table 4 and Table 5.

Table 4. Contingency table between question 4 and question 3

3. Did you have the opportunity to interact with all your teammates?	4. Did you feel your teamwork improved during the project?		
	Somewhat	Very	Total
Somewhat	1	1	2
Very	1	31	32
Total	2	32	34

Table 5. Chi-Squared Analysis

Chi-Squared Tests	Value	df	p
χ^2	7.471	1	0.006

Table 6. Contingency table between question 8 and question 3

3. Did you have the opportunity to interact with all your teammates?	8. What is your overall level of satisfaction with the Karate instructional project?		Total
	Somewhat	Very	
Somewhat	1	1	2
Very	1	31	32
Total	2	32	34

Table 7. Chi-Squared Analysis

Chi-Squared Tests	Value	df	p
χ^2	7.471	1	0.006

Next, the second relationship found was between question 8 'What is your overall satisfaction level with the Karate instructional project?' and question 3 'Did you have the opportunity to interact with all your teammates?', resulting in $p = 0.006$. The whole can be observed in Table 6 and Table 7.

Discussion

From the responses provided by the participants in the questionnaire, an overall positive picture emerges regarding the experience with the Karate Game. In particular, from the results that emerged, it is evident that the Karate Sports Game elicited a positive impact on their emotional state. This indicates that the playful approach adopted helped to make the experience enjoyable and engaging for the children, fostering a positive and motivating learning climate. An interactive and dynamic environment was created in which children could actively participate (Altavilla et al, 2022). This type of involvement promotes experiential learning, in which we improve through action and direct experience, rather than through mere observation or passivity. In this setting, participants learned informally, without feeling pressured or judged. The environment also encouraged exploration and experimentation, allowing everyone to acquire new skills naturally and gradually. A series of progressive challenges were created, adapted to the skill level of the sample. This allowed the components to experience a sense of success and satisfaction when they overcame difficulties, encouraging them to persevere and improve despite the obstacles they encountered. Interaction and collaboration with peers was promoted during the activity, developing important social skills such as communication, sharing and conflict management. Another significant finding was the strong consensus regarding improved game skills and the perceived improvement in teamwork. These findings suggest that Karate Game not only promoted the development of motor skills, but also promoted collaboration and cooperation among participants, thus helping to strengthen group dynamics (D'Isanto et al, 2024). Also interesting is the observation that the instructions for the game activities were considered clear and easy to follow by the vast majority of participants (Esposito et al, 2024). This indicates an adequate level of communication and support from the instructors, who facilitated active participation and understanding of the proposed activities. In addition, previously conducted studies, (Lakes et al, 2004), analyzed the impacts of Karate on children's cardiorespiratory function and flexibility, showing significant improvements in both domains. This supports the idea that Karate may not only contribute to motor development but also to the general well-being of children (D'Elia et al, 2023). The promotion of moral and social values through Karate has been investigated by research highlighting the role of martial arts in promoting social values. Aspects, also reinforced by the significant relationships had in the present study. The significant relationships found among the qualitative variables, particularly regarding improvement in teamwork and overall

satisfaction with the project, highlight the importance of social interaction and collaboration in the overall experience of the participants. These results underscore the effectiveness of the Karate Game in promoting not only motor skills, but also values such as respect, integrity, and honor, which are fundamental to the martial arts.

Conclusion

The present study investigated the effectiveness of structured Karate Game sessions in the motor development and psychosocial well-being of participants. From the results from the questionnaire responses, it is clear that Karate Play is a highly positive approach to engage children in physical activities, improve motor skills, and promote key martial arts values such as respect, integrity, and honor. The wide participation and positive feedback from participants indicate that the design had a significant impact on their experience, both in terms of improved emotional state and involvement during the sessions and perceived improvement in motor skills and group dynamics. In addition, the significant relationships found between some qualitative variables, such as improved teamwork and overall satisfaction with the project, highlight the importance of social interaction and collaboration in the proposed activity. These results suggest that this educational methodology represents not only an opportunity for children's motor and physical development, but also a valuable context for the promotion of social and emotional values and skills, crucial for their future well-being and success. Ultimately, Karate Game is presented as an important educational and training resource, capable of combining fun, learning and the promotion of positive values, thus contributing to the complete development of personality and motor, cognitive and emotional development during developmental age. However, it is important to consider that this study involved a specific sample, and further research may be needed to confirm and deepen these findings.

Conflict of interest

The authors declare that there is no conflict of interest.

References

- Raiola, G., D'Isanto T., Di Domenico, F., D'Elia, F. (2022). Effect of Teaching Methods on Motor Efficiency, Perceptions and Awareness in Children. *International Journal of Environmental Research and Public Health*, 19(16), art. no. 10287. <https://doi.org/10.3390/ijerph191610287>
- D'Elia, F., D'Isanto, T., Esposito, G., Altavilla, G., Raiola, G. (2023). Physical activity and sports science in Italian scientific research products. *Health, Sport, Rehabilitation*, 9(2), 38-47. <https://doi.org/10.34142/HSR.2023.09.02.03>
- Kail, R. V. (2000). *Children and Their Development* (2nd ed.). Prentice-Hall.
- Piek, J. P., et al. (1999). Motor coordination and kinaesthesia in boys with attention deficit-hyperactivity disorder. *Developmental Medicine & Child Neurology*, 41(3), 159-165.
- Di Domenico, F., D'Isanto, T., Esposito, G., Aliberti, S., Raiola, G. (2023). Exploring the Influence of Cognitive and Ecological Dynamics Approaches on Countermovement Jumping Enhancement: A Comparative Training Study. *Journal of Functional Morphology and Kinesiology*, 8(3), art. no. 133. <https://doi.org/10.3390/jfmk8030133>
- Di Domenico, F., Esposito, G., D'Isanto, T., Aliberti, S., Raiola, G., (2023). Physical performance in masters' degree students in Exercise and Sport Sciences related to the motor learning approach. *Motricidade*, 19(4). <https://doi.org/10.6063/motricidade.32629>
- Raiola, G., D'Elia, F., Esposito, G., Altavilla, G., D'Isanto, T. (2023). The accountability of football as a form of public good on local communities: a pilot study. *Physical Education Theory and Methodology*, 23(2), 263-270. <https://doi.org/10.17309/tmf.2023.2.15>
- D'Isanto, T., D'Elia, F., Esposito, G., Altavilla, G., Raiola, G. (2022). Examining the Effects of Mirror Therapy on Psychological Readiness and Perception of Pain in ACL-Injured Female Football Players. *Journal of Functional Morphology and Kinesiology*, 7(4), art. no. 113. <https://doi.org/10.3390/jfmk7040113>
- D'Isanto, T., Di Domenico, F., Aliberti, S., D'Elia, F., Raiola, G. (2022). Criticisms and perspectives of heuristic learning in physical education. *Pedagogy of Physical Culture and Sports*, 26(2), 93-100. <https://doi.org/10.15561/26649837.2022.0203>
- Raiola, G., D'Elia, F., Esposito, G., Altavilla, G., D'Isanto, T. (2023). The accountability of football as a form of public good on local communities: a pilot study. *Physical Education Theory and Methodology*, 23(2), 263-270. <https://doi.org/10.17309/tmf.2023.2.15>
- Altavilla, G., Ceruso, R., Esposito, G., Raiola, G., D'Elia, F. (2022). Physical education teaching in Italian primary school: theoretical lines and operational proposals. *Pedagogy of Physical Culture and Sports*, 26(3), 151-157. <https://doi.org/10.15561/26649837.2022.0302>
- Altavilla, G., Aliberti, S., D'Isanto, T., Raiola, G. (2022). A comparison between ecological-dynamic and cognitive approach to improve accuracy in basketball shot. *Studia Sportiva*, 16(1), 6-12. <https://doi.org/10.5817/StS2022-1-1>
- Chaabène, H., et al. (2017). Effects of a Karate program on body composition, and motor abilities of adolescent. *Advances in Physical Education*, 7, 197-206.
- D'Elia, F., D'Andrea, D., Esposito, G., Altavilla, G., Raiola, G. (2021). Increase the performance level of young basketball players through the use of high intensity interval training. *International Journal of Human Movement and Sports Sciences*, 9(3), 445-450. <https://doi.org/10.13189/saj.2021.090308>
- D'Isanto, T., Aliberti, S., Raiola, G., D'Elia, F. (2024). Assessment of motor skills in 5-6 year old Italian children using the MABC-2: a preliminary study. *Physical Activity Review*, 12(1), 112-120. <https://doi.org/10.16926/par.2024.12.11>
- Esposito, G., Di Domenico, F., Ceruso, R., Aliberti, S., & Raiola, G. (2024). Perceptions/opinions about the formation of the bachelor program in exercise and sports science by students aimed at the new professional profile of the basic kinesiologist. *Sport Sciences for Health*, 20(2), 659-664. <https://doi.org/10.1007/s11332-023-01139-8>
- Lakes, K. D., Bryars, T., & Sirisinalhal, S. (2004). The healthy for life project: Physical fitness outcomes. *Research Quarterly for Exercise and Sport*, 75(1), 60-69.
- D'Elia, F., D'Isanto, T., Esposito, G., Altavilla, G., Raiola, G. (2023). Physical activity and sports science in Italian scientific research products. *Health, Sport, Rehabilitation*, 9(2), 38-47. <https://doi.org/10.34142/HSR.2023.09.02.03>

Карате-гра: застосування ігрового та партисипативного підходу щодо покращення соціальної та рухової перцепції дітей у віковому періоді розвитку

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

Реферат. Стаття: 6 с., 7 табл., 18 джерел.

Мета дослідження. Метою дослідження було оцінити вплив специфічних для спорту освітніх пропозицій у шкільному віці, які наразі використовуються при плануванні спортивних заходів, таких як заняття з карате із застосуванням ігрової моделі тренувального процесу, на соціальну взаємодію та покращення рівня сприйняття власних рухових навичок.

Матеріали та методи. Вибірка складалася з 34 дітей із Загальноосвітнього інституту «Матильда Серао» в Ортоні, провінція К'єті, які навчалися у третій класі початкової школи у 2023/2024 навчальному році. В основу методу було покладено протоколи спортивних ігор з карате в поєднанні з популяризацією етичних принципів, притаманних бойовим мистецтвам. Було розроблено опитувальник з метою оцінки рівня задоволеності учнів, а також їхнього власного сприйняття та ставлення до інших під час проведення цієї тренувальної інтервенції.

Результати. Оцінка результатів освітніх пропозицій, що проводилася після завершення реалізації проекту, показала, що 94,1 % учасників мали позитивний досвід участі у заняттях з карате із застосуванням ігрової моделі, 82,3 % повідомили, що відчували значну підтримку з боку інструкторів під час проекту, а 94,1 % учасників залишилися дуже задоволеними заняттями. Використання критерію хі-квадрат виявило два значущі взаємозв'язки щодо концепції можливості взаємодії з усіма однолітками. Перший був пов'язаний із загальною задоволеністю учасників навчальним проектом з карате ($p = 0,006$), тоді як другий стосувався концепції покращення командної роботи ($p = 0,006$).

Висновок. Результати дослідження вказують на позитивний вплив карате-гри на емоційну сферу учасників, рівень залученості, відчутне поліпшення рухових навичок та групову динаміку. Крім того, встановлені значущі взаємозв'язки підкреслюють важливість соціальної взаємодії та спільних дій у контексті фізичної активності. Отримані результати свідчать про те, що застосування ігрового та партисипативного підходу в процесі тренувальних занять з карате може виступати в якості цінного ресурсу щодо комплексного формування особистості та рухових навичок у дітей впродовж вікового періоду розвитку.

Ключові слова: бойові мистецтва, особистість, рухові навички, інноваційні методики, сприйняття, взаємозв'язки.

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Identifying the Peculiarities of Students' Aggressive Behaviour in Physical Education Lessons

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

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Abstract

Background. Recently, a lot of special attention has been paid to the school environment where students' aggressive behaviour that spreads quickly is getting more expressed and reflects processes in the modern society and their consequences for the young generation. It can often have various short- and long-term consequences for a student's behaviour, communication with others, emotional state or his/her self-esteem. Thus, this complex situation encourages to get interested in understanding the underlying causes of students' aggressive behaviour and peculiarities of its frequent manifestation.

Objectives. The study aimed to reveal the peculiarities of students' aggressive behaviour expression in physical education lessons in the context of age and gender aspects.

Material and methods. A total of 197 students participated in the study, comprising 52 girls aged 12-13 years, 44 boys of the same age group, 60 girls aged 14-15 years and 41 boys of the same age.

Results. The findings of the study indicated that 14-15-year-old students were more prone to the following forms of aggressive behaviour in physical education lessons: negativism, offence, irritation, physical and verbal aggression compared with 12-13-year-old students. It was also determined that older students demonstrated statistically significant higher levels of hostility and aggressiveness than younger counterparts. When analysing the students' aggressive behaviour in the aspect of gender, it was found that boys often expressed the following forms of aggressive behaviour: negativism, offence, irritation and physical aggression; meanwhile, girls were more prone to the feeling guilty and verbal aggression. Higher hostility is more characteristic to boys than to girls, but the aggressiveness observed in the groups of boys and girls was assessed similarly according to the aggressiveness index.

Conclusions. The results obtained could be subjected to further analysis in order to enhance their effectiveness, for example, by examining concrete life situations of students.

Keywords: aggressive behaviour, forms of aggressive behaviour, students, physical education lesson.

Introduction

The topic of aggression-prone students has been discussed for several decades, but it is one of the most relevant problems of our society. Students' aggressive behaviour is one of the biggest evils of social life that is progressing quickly in the modern society and getting an integral part of our life. Aggressive behaviour is expressed in all the periods of human age, but it is especially dangerous in the period of adolescence as it is tried to solve arising problems and hide the feeling of insecurity and uncertainty with this kind of

behaviour. It is supposed students behave in an aggressive manner because they try to be popular among their peers and want to draw attention (Šeibokaitė, 2008; Lloyd et al., 2008). In the scientific literature, aggressive behaviour is often understood as any hostile behaviour in respect of another person or group of people by demonstrating the advantage rudely and using force occasionally. It is not doubted today's changes of life have encouraged these outbreaks of behaviour and the number of cases of students' aggressive behaviour has grown significantly. Moreover, Palujanskienė and Uzdila (2004) state that students must be encouraged and trained to suppress aggression in the school community and teachers must first organize the activity for students, solve problems of their business and teach to solve conflicts in a constructive way in order to eliminate aggressive behaviour. Nevertheless,

a lot of authors: ZinatMotlagh et al. (2013), Amadi et al. (2015), Jiménez & Estévez (2017) suppose reasonably that school is the place where aggressiveness is first expressed and the problem of aggressiveness remains undoubtedly relevant due to long-term consequences at schools. Moreover, it is stated in several studies the likelihood of aggressive behaviour is higher if the school training process fails to comply with the students' needs and interests related with changes in the society (Barkauskaitė, 2001; Olivier, 2003).

When analysing scientific studies of the recent period, it can be noticed more and more attention is paid for the determination of qualitative differences in students' aggressive behaviour and it is not confined with the qualitative assessment only (Hopkins et al., 2013; Farrell et al., 2017) moreover, scientists pay much more attention to the interventive measures of students' aggressive behaviour and effectiveness of preventive programs (Wade et al., 2018; Yanagida et al., 2019; Trajković et al., 2020). In previous studies, it was tried to find an answer to the question in what way students' aggressive behaviour depends on gender and it was assumed in most studies that boys are more aggressive than girls and are often initiators of aggression (Boulton & Underwood, 1993; Owens & MacMullina, 1995; Björkqvist, 2018). For example, Jančiauskas (2018) had a purpose to reveal the difficulties in the behaviour of higher form students at school and states that boys from higher forms mostly used physical aggression and girls use verbal aggression for the solution of conflicts. However, these assumptions are made quite carefully nowadays as there proofs according to which it can be stated that girls behave in the same aggressive or even more aggressive way taking into account certain forms of aggression. Authors Österman et al. (1998) who analysed aggressive behaviour of 8, 11 and 15-year-old adolescents (girls and boys) from Finland, Israel, Italy and Poland confirmed that the girls from these countries mostly used indirect aggression, the second kind of aggression was verbal and the rarest kind of aggression was physical. The study performed by Card and co-authors (2008) overviews and sums up 148 scientific studies about aggressive behaviour of children and adolescents in the aspect of gender. The results of this study allow supposing there are differences of aggressive behaviour between genders, girls and boys are assessed similarly according to verbal aggression, but boys are more aggressive according to physical aggression and girls – according to indirect aggression. Scientists from South Korea Chung et al. (2019) pay much attention to the studies of indirect aggression among children and emphasize this kind of aggression is an imperceptible form of behaviour that is difficult to find, so lots of difficulties are often encountered in order to assess it. It shows the way of changing the society's attitude towards the peculiarities of aggressive behaviour which are characteristic to individual genders.

When overiewing the scientific literature, it can be noticed there is no unanimous agreement among all the authors that students' aggressive behaviour often depends on gender; the search for an answer to the question if students' aggressive behaviour is affected by age also causes lots of discussions.

For example, Žukauskienė (1999) was one of the first persons of Lithuania that performed a complex study in order to check the hypothesis if the forms of aggressive behaviour

among 8-14-year-old children depend on their gender and age. The study data shows children use indirect aggression in the course of age more and more often. The insight indicated in the study that younger children whose verbal and social abilities are not well-developed are inclined to use physical aggression must also be mentioned. In the development of social competences, it is learned to use indirect aggression, i.e., the aggressor learns to do psychological and sometimes even physical harm without risking to be identified. Meanwhile, Jančiauskas (2018) analysed the reasons for difficulties in the behaviour of higher form (15-19-year-old) students and problems of their behaviour at school, but these reasons were indicated in a general manner and not about individual age groups. In the studies published by other scientists it was also searched for differences in aggressive behaviour among higher form students and tried to assess the influence of age and gender on aggressive behaviour (Shaikh et al., 2014). When analysing publications about the researched topics (Gudžinskienė & Burvytė, 2017) revealed an interesting remark in their study: one of the least safe places of school where students show aggressiveness is a sport hall; it was even mentioned by 49.1 percent 12-16-year-old students who participated in the study. These results encouraged to perform a study in order to assess the peculiarities of students' aggressive behaviour in physical education lessons taking account their gender and particularity of age that can affect various transformations of aggressive behaviour. On the basis of literature insights, it can be stated it would also be useful to analyse students' aggressive behaviour in this context empirically as new study data would allow expanding the understanding of aggressive behaviour much more and the assessment of this behaviour would be able to draw more attention to the necessity of interventive measures for aggressive behaviour and it would be searched for effective measures. The newness of this study is revealed as it is tried to look at the expression of students' aggressive behaviour in physical education lessons from the position of students.

Materials and Methods

Study Participants

When applying the accidental serial selection procedure (according to tables of random numbers), six schools from the list of comprehensive schools of Lithuanian cities got to the sample. 211 questionnaires were distributed during the research, but 197 questionnaires were suitable for the analysis of the research. Before the research, the researched were divided into two groups, the first group consisted of 52 12-13-year-old girls and 44 boys and the second group consisted of 60 14-15-year-old girls and 41 boys.

Study Organization

Before researching the expression of forms of students' aggressive behaviour in physical education lessons, oral agreements about the participation in the research were received from the school administration and students' parents. The research was performed before physical education lessons in the long break after pre-agreeing with the school administration. The students filled out the

questionnaire for 15-20 minutes. During the research, the main ethic principles which are characteristic to social studies: justice, good will, anonymity and confidentiality were observed.

Principle of justice. During the research, it was ensured the conditions will be created for each participant to get involved in the research voluntarily, it was also explained according to which criteria they were chosen and why they were invited to participate in the research. The researched were enabled not to answer certain questions of the research in case they felt uncomfortable. **Principle of good will.** The importance and the benefit of the research were explained to the participants in order to motivate them to take part in the research. Each researched had a possibility to make a decision and refuse to take part in the research. **Principle of anonymity.** When realizing this principle, no personal information that allows identifying a certain person was used. For example, the participants were not asked to indicate their name or surname and school where they learned. **Principle of confidentiality.** The application of this principle obligated that all the information about the research participants and analysed material will be accessible to the researcher only. The researched were also explained about the use of collected data and storage of the researched material.

The Buss Durkee Hostility Inventory was chosen for the revelation of the researched topics (Vassar & Hale, 2009). The Buss Durkee Hostility Inventory consists of 75 question and each statement of the questionnaire must be assessed by answering the statement: "YES" – 1 point or "NO" – 0 points. This questionnaire allowed assessing different forms of the expression of students' aggressive behaviour: negativism, offence, suspiciousness, irritation, feeling guilty, physical, verbal and indirect aggression.

Negativism is a form of behaviour directed against a certain authority or organization head that can be expressed from passive objection to active acts against requirements, rules, laws or instructions. Offence is envy and hatred for the people round about that is expressed as anger, revenge, dissatisfaction with something or the total world because of real or imagined sufferings. Suspiciousness is an inclination to distrust and careful communication with people due to convictions that the people round about want or can harm. Irritation is an inclination to irritation, preparation to give a loose to feelings because of the minimum worry and it is expressed as rudeness and roughness in the communication (Vassar & Hale, 2009). Feeling guilty is acts and their consequences to the own personality and the people round about arising from the conviction the person is bad and behaves badly, improperly, so it conditions appropriate assessment of the own personality and other people and behaviour. Physical aggression is the use of physical force against another person. Indirect aggression is expressed against another person (gossip, jokes, various non-verbal reactions: face, eye contact, gestures, other moves of the body, posture etc.). Verbal aggression is an expression of negative feelings by using a certain form of the oral appeal (scream, dispute, threatening, conflict) between two or more persons (Vassar & Hale, 2009).

The calculated hostility index consists of the following components: irritation, expression of offence, suspiciousness and negativism. The determined aggressiveness index consists of physical, indirect and verbal aggression.

The hostility index (HI) was calculated according to the following formula: $HI = (\Sigma N + \Sigma SR + \Sigma I + \Sigma S)/4$, where ΣN is the final sum of points of scale 1 (negativism), ΣSR is the final sum of points of scale 2 (offence), ΣI is the final sum of points of scale 3 (suspiciousness), ΣS is the final sum of points of scale 4 (irritation). The aggressiveness index (AI) was calculated according to the following formula: $AI = (\Sigma FA + \Sigma NA + \Sigma VA)/3$, where ΣFA is the final sum of points of scale 6 (physical aggression), ΣNA is the final sum of points of scale 7 (indirect aggression), ΣVA is the final sum of points of scale 8 (verbal aggression).

The meanings of the Cronbach alpha correlation coefficients from 0.708 to 0.863 were calculated for the assessment of the internal consistency of the questionnaire scales (Table 1). The acceptable threshold according to Taber (2018) is > 0.7 .

Table 1. Scales of the Buss Durkee Hostility Inventory and suitability indexes

No.	Scale name	Statement numbers	Cronbach a
1.	Negativism	4, 12, 20, 28, 36*	0.863
2.	Offence	5, 13, 21, 29, 37, 44, 51, 58	0.744
3.	Suspiciousness	6, 14, 22, 30, 38, 45, 52, 59, 65*, 70*	0.829
4.	Irritation	3, 11*, 19, 27, 35*, 43, 50, 57, 64, 69*, 72	0.711
5.	Feeling guilty	8, 16, 24, 32, 40, 47, 54, 61, 67	0.821
6.	Physical aggression	1, 9*, 17*, 25, 31, 41, 48, 55, 62, 68	0.708
7.	Indirect aggression	2, 10, 18, 26*, 34, 42, 49*, 56, 63	0.765
8.	Verbal aggression	7, 15, 23, 31, 39*, 46, 53, 60, 66*, 71, 73, 74*, 75*	0.812

Note. The answers of the questions marked with sign * are assessed: "YES" – 0 points, "NO" – 1 point

Statistical Analyses

As the data distribution of the Buss Durkee Hostility Inventory was compliant with the normal distribution, the parameter Student t-test was used for independent samples. The obtained data is considered statistically significant in case they meet the significance level $p < 0.05$. The arithmetic mean (M) and the standard deviation (SD) were calculated for the comparison of the research data. The statistical data analysis was performed by using the app package for the data accumulation and analysis: SPSS 26.0 (Statistical Package for Social Science 19 for Windows).

Results

By using the Buss Durkee Hostility Inventory, it was tried to assess the expression of students' aggressive behaviour in physical education lessons, the means of forms of aggression and standard deviations were calculated in this respect and the *Student t-test* was used for the determination of the reliability of differences between the groups.

Table 2. Statistical indicators of aggressive behaviour in physical education lessons by age

Aggressive behaviour	Age	n	M	SD	t	p
Negativism*	12-13	96	3.59	0.49	-10.43	p < 0.05
	14-15	101	4.41	0.61		
Offence*	12-13	96	4.87	0.54	-8.34	p < 0.05
	14-15	101	5.65	0.76		
Suspiciousness	12-13	96	6.91	0.79	1.72	p > 0.05
	14-15	101	6.73	0.67		
Irritation*	12-13	96	7.12	0.68	-9.19	p < 0.05
	14-15	101	8.05	0.74		
Feeling guilty	12-13	96	7.15	0.72	-1.92	p > 0.05
	14-15	101	7.34	0.67		
Physical aggression*	12-13	96	5.92	0.56	-8.78	p < 0.05
	14-15	101	6.74	0.74		
Indirect aggression	12-13	96	6.03	0.53	1.84	p > 0.05
	14-15	101	5.88	0.61		
Verbal aggression*	12-13	96	7.75	0.45	-9.42	p < 0.05
	14-15	101	8.49	0.64		

Note. * – p < 0.05 when comparing the mean scores of students of different ages

The results of the research revealed that certain forms of students' aggressive behaviour in physical education lessons are more characteristic to higher form students (in our case, 14-15-year old ones) than to younger ones (in our case, 12-13-year-old ones). The analysis of the results showed reliably different assessments of the both groups of students in respect of negativism, offence, irritation, physical and verbal aggression (Table 2).

It was determined the mean of negativism is higher for 14-15-year-old students compared with 12-13-year-old ones (4.41 ± 0.61 and 3.59 ± 0.49 , respectively; $p < 0.05$). It allows supposing older students have a negative inclination more often, are inclined to resist, reject help, argue and do not want to obey the teacher's instructions. Offence is also more characteristic to older students (5.65 ± 0.76 , $p < 0.05$). It allows supposing older students are inclined to perform an incorrect act against another person more often.

After comparing the data of irritation among 12-13-year-old and 14-15-year-old students, it can be seen the mean of the results among older students (8.05 ± 0.74) is higher than among younger ones (7.12 ± 0.68 ; $p < 0.05$). In these situations, students can feel more often that violence is used against them, they suffer from unfairness and they are threatened or prohibited something unfoundedly. It is also supposed more often in these situations it is prevented from satisfying certain needs or reaching for goals.

It can be noted statistically reliable differences were determined after comparing the results of the research performed with the students of different age groups for the following forms of aggressive behaviour: physical and verbal aggression. According to the data of this research, the means of the results of physical and verbal aggression used by older students (6.74 ± 0.74 and 8.49 ± 0.64) are higher compared with younger ones (5.92 ± 0.56 and 7.75 ± 0.45 , respectively). Taking this into account, it can be assumed that 14-15-year-

old students are more inclined to escape from an unpleasant, tensed psychical state or conflict situation with the help of their aggressive behaviour as well as communicate with their peers in a more aggressive way in order to reach the goal. Meanwhile, the results of the research showed there was no statistically reliable difference between the students from the both groups in respect of suspiciousness, feeling guilty and indirect aggression (Table 2).

After determining the generalized hostility index and calculating the mean from the results of four scales, it can be seen the hostility index was (6.21 ± 0.69) for 14-15-year-old students and (5.61 ± 0.63) for 12-13-year-old students. It means the hostility of older students is expressed more strongly statistically reliably ($t_{(195)} = -6.38$; $p < 0.05$) (Figure 1).

After determining the generalized aggressiveness index, i.e., calculating the mean from the results of three scales, it can be seen the aggressiveness index was (7.04 ± 0.66) for 14-15-year-old students and (6.57 ± 0.51) for 12-13-year-old students. These indexes show aggressiveness is more characteristic to students from the older group statistically reliably ($t_{(195)} = -5.61$; $p < 0.05$) (Figure 1).

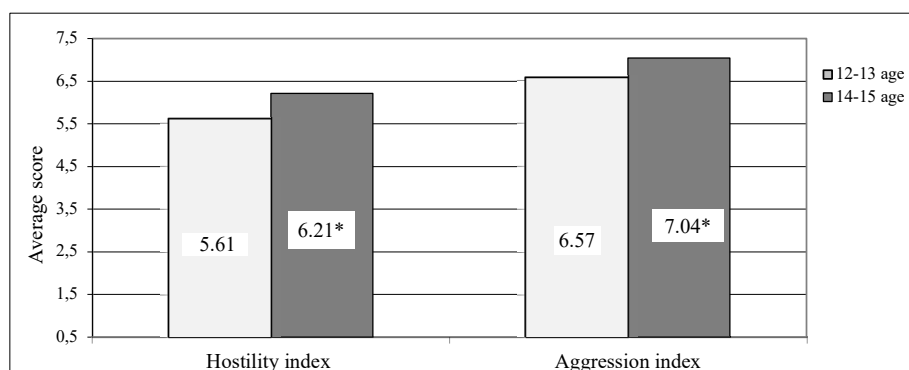
In the study, we both tried to reveal the peculiarities of the expression of aggressive behaviour in students of different age in physical education lessons and analysed in what way it depends on the gender of students. The analysis of the results allows stating that the expression of aggressive behaviour in physical education lessons is different for girls and boys. According to the research data, boys assessed some forms of the expression of aggressive behaviour with statistically reliably higher indexes (Table 3).

It can be seen the mean of boys' negativism (4.04 ± 0.69) is higher than that of girls (3.29 ± 0.62 ; $p < 0.05$). The mean of the assessment of offence is also higher in the group of boys (6.44 ± 0.69). After comparing the irritation data of boys and girls, it was revealed that the mean of the boys'

Table 3. Statistical indicators of students' aggressive behaviour in physical education lessons by gender

Aggressive behaviour	Gender	n	M	SD	t	p
Negativism*	Girls	112	3.29	0.62	-7.89	p < 0.05
	Boys	85	4.04	0.69		
Offence*	Girls	112	5.57	0.55	-9.27	p < 0.05
	Boys	85	6.44	0.72		
Suspiciousness	Girls	112	7.09	0.47	1.92	p > 0.05
	Boys	85	6.93	0.65		
Irritation*	Girls	112	7.98	0.81	-2.15	p < 0.05
	Boys	85	8.21	0.69		
Feeling guilty*	Girls	112	6.87	0.93	6.64	p < 0.05
	Boys	85	6.14	0.61		
Physical aggression*	Girls	112	6.49	0.69	-10.83	p < 0.05
	Boys	85	8.04	0.98		
Indirect aggression	Girls	112	5.76	0.56	1.80	p > 0.05
	Boys	85	5.59	0.72		
Verbal aggression*	Girls	112	7.75	0.78	8.61	p < 0.05
	Boys	85	6.91	0.59		

Note. * – p < 0.05 when comparing the mean scores for girls and boys

**Fig. 1.** The Mean scores of hostility and aggression indexes in the 12-13 and 14-15 age groups

Note * – p < 0.05 statistically significant difference

results (8.21 ± 0.69) is higher than that of girls (7.98 ± 0.81 ; $p < 0.05$). However, the results of the research showed higher indexes of feeling guilty in the group of girls (6.87 ± 0.93 and 6.14 ± 0.61 , respectively; $p < 0.05$), it allows stating girls suffer from this feeling more often. The feeling guilty is mostly caused by the understanding that the behaviour infringes important social or moral norms. It is also assumed this feeling can be related with the frequent self-assessment and feeling of higher responsibility and self-criticism in girls. The research showed there was no reliable difference in the statistical indexes for the students of both groups. Thus, it can be emphasized the assessments of students' suspiciousness would be similar irrespective of the situation (Table 3).

The generalized indexes of the expression of aggressive behaviour in girls and boys – hostility and aggressiveness indexes – are also analysed in the study. When analysing the results, we noticed different assessments of the hostility index by the students of both groups. The boys' hostility

index was assessed with a statistically reliably higher mean 6.41 ± 0.69 compared with the girls – 5.98 ± 0.61 ; ($t_{(195)} = -4.55$; $p < 0.05$). It allows supposing boys are more inclined to make other people to behave in the way that would meet their personal expectations. Students with a hostile inclination are accompanied by outbreaks of anger, irritation, inclination to violence, wish to harm, humiliate or cause pain to other people. However, it can be noticed the data of our research shows there is no statistically reliable difference in the students of different genders according to the assessment of the aggressiveness index ($t_{(195)} = -1.82$; $p > 0.05$).

It is shown in the means of the aggressiveness index as a generalized index 6.66 ± 0.67 for girls and 6.85 ± 0.76 for boys. To sum up the aggressiveness indexes, it can be seen there was no statistically reliable difference in the assessments of just one of three scales, so it cannot be stated unambiguously the assessments of this index do not depend on the students' gender (Figure 2).

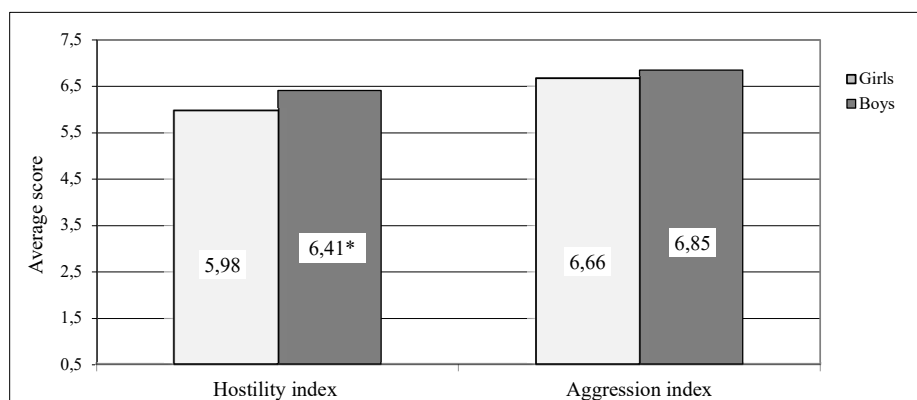


Fig. 2. The Mean scores of hostility and aggression indexes for girls and boys in groups

Note * – $p < 0.05$ statistically significant difference

Discussion

The analysis of the study of aggressive behaviour allows stating that students' aggressive behaviour can both depend on their gender and on their age. The comparison of the results of the performed research with other researches is complicated because most studies used different aggression assessment scales. However, quite contradictory results can be seen when comparing similar studies – some researchers state that gender differences have the biggest influence on students' aggressive behaviour (Card et al., 2008; Björkqvist, 2018), meanwhile, others pay attention to the aspect of age (Shaikh et al., 2014; Jančiauskas, 2018), other researchers treat this problem in a complex way and accentuate the importance of gender and age (Žukauskienė, 1999). According to Amedahe & Owusu-Banahene (2007), boys' aggressive behaviour under competitive conditions is often expressed as direct aggression, such as physical aggression; meanwhile, girls are inclined to use indirect aggression and the reason for it is differences in the structure of peer groups of boys and girls. Moreover, there are more scientific studies, for example, Žukauskienė (1999) states that boys are much more active and physically stronger than girls, so direct – both physical and verbal – aggression is more characteristic to them and indirect aggression is more characteristic to girls; it also confirms our results partially. We think we can support the conclusions of Amedahe & Owusu-Banahene (2007) stating that boys are prone to such forms of direct aggression as physical aggression more often. On the basis of the data obtained in the meta-analysis of Card and co-authors (2008), it can be noted boys are more aggressive than girls, but they are prone to indirect aggression. The results obtained during the studies performed by Crick & Werner (1998) with the purpose to analyse the attitude of girls and boys towards certain forms of aggression were a little different. In the girls' attitude, indirect aggression is much stronger and effective than direct aggression; meanwhile, boys think direct aggression is more harmful. It shows boys and girls choose such forms of aggression which seem to them more effective or harmful. This remark allows stating that aggressiveness is not different in boys and girls, but there is a difference in the forms of the expression of aggressiveness due to a different understanding of harm. Nevertheless, it can be supposed additional studies are necessary in order to substantiate these assumptions. We think the latter statement is better for the

interpretation of the data of our research about students' aggressive behaviour in physical education lessons as students often suffer from negative feelings in competitive situations and are not always able to control their behaviour successfully.

Meanwhile, scientists Gudžinskienė & Burvytė (2017) were interested in students' attitude towards the present situation at school: they were looking for answers which aggressive acts affect students, the school microclimate, in which forms aggressiveness is expressed, in what way students react to this kind of behaviour. It is noted in this research both verbal and physical aggression is encountered at school, but attention should also be paid to electronic aggression. It reveals students' aggressive behaviour is obtaining new forms, but we cannot compare this research with our study as it does not go deep into the differences of aggressive behaviour in the aspects of gender.

The generalized indexes of forms of the expression of aggressive behaviour – hostility and aggressiveness index – were analysed in our study. After determining the generalized hostility index, i.e., calculating the mean from the results of four subscales, it emerged that boys' hostility is higher statistically reliably ($p < 0.05$) compared with girls. When interpreting the research data, the insights of some researchers can be supported: the change of these results can be affected by the fact that boys encounter the hostility of the social environment and difficulties at school (Amadi et al., 2015), higher mobility, rude demonstration of the advantage (Lloyd et al., 2008) or even use of force against a peer group (Wakoli et al., 2016) more and more often. However, taking into account the results, it can be noticed that the aggressiveness indexes are both similar for girls and boys and there is no statistically significant difference ($p > 0.05$). It allows contradicting the conclusions of some specialists of aggressive behaviour stating that boys are more aggressive (Owens & MacMullina, 1995; Archer et al., 1988; Rozzaqyah et al., 2021). According to Archer (2000), it is emphasized in the meta-analysis that ambiguous results of the research in this field depend on different instruments used for the measurement of aggression and individual characteristics of adolescents. Meanwhile, some studies state this difference between the genders can only be found when analysing aggressive behaviour, especially in the group of abusing people (Moretti et al., 2001).

When analysing the peculiarities of students' aggressive behaviour, we will both discuss in what way this kind of behaviour depends on gender and on age. Our results revealed that 14-15-year-old students express negativism, offence, irritation, physical and verbal aggression statistically significantly more often compared with 12-13-year-old students. Meanwhile, other researchers (Shaikh et al., 2014) state that aggressive behaviour is both characteristic to boys and girls; it was also determined physical aggression increased from the seventh form to the tenth form significantly. Verbal aggression was found in boys quite early, but the tendency of decrease was noticed before the tenth form. Meanwhile, the tendency of the increase of verbal aggression was noticed in girls from the seventh form to the tenth form. However, aggressive behaviour of older students is analysed in the studies of the above-mentioned authors, so these differences cannot be interpreted as absolutely compatible with our data. In the other study, the differences of aggressive behaviour are discussed and the age groups of 8-9, 11-12, 13-14-year-old children are taken into account, Žukauskienė (1999) accentuates the increase of physical, verbal and indirect aggression in the course of age in all these groups. We can support this position as our results confirm similar conclusions that such forms of aggressive behaviour as negativism, offence, irritation, physical and indirect aggression are much more expressed in the group of 14-15-year-old students than in the group of younger 12-13-year-old students. It can also be stated that the hostility and aggressiveness indexes generalized in the group of older students participating in our study were higher. Moreover, there are some studies which analyse aggression of sport-doing and non-sport-doing students in a quite comprehensive way (Jančiauskas, 2018a), but we assessed the peculiarities of aggressive behaviour in much younger students, so we cannot assess if this data is similar or contradicts to our results.

To sum up the research data, the limitations of the research and perspectives of further research must also be considered. One of the essential limitations is a small sample of the researched in this study; moreover, we researched younger students, but the samples of most analysed studies were often formed from older students. In this aspect, the comparison of the results of our research with the data obtained by other researchers is quite limited. In order to compare the results of the research in a more comprehensive way, it is necessary to strive for higher equivalency of researched groups; otherwise, it will be difficult to interpret the results. It should also be mentioned the research was performed during breaks, so the researched may have filled out the questionnaire not very objectively and give similar answers like their friends. The conclusions should also be assessed carefully as they are only based on the students' self-assessments, so the answers to the questions may have been partial. The latter limitations of the research can also affect the results. Taking into account the limitations of this research, it would be useful to make significant conclusions by generalizing the results of the research; it would also be useful to perform additional research in the future by involving teachers and students' parents who would be able to notice the difficulties of improper behaviour, so their assessments should be considered and included in the analysis. More comprehensive research is necessary in

order to obtain more accurate data about the peculiarities of aggressive behaviour of younger students.

Conclusions

When applying the Buss Durkee Hostility Inventory, it was revealed that 14-15-year-old students are more inclined to express the following forms of aggressive behaviour in physical education lessons: negativism offence, irritation, physical and verbal aggression compared with 12-13-year-old students. It was also determined older students can be characterized with statistically reliably higher hostility than younger ones. When analysing students' aggressive behaviour by gender, it was revealed that boys are prone to the following forms of aggressive behaviour: negativism, offence, irritation and physical aggression statistically reliably more often than girls. Meanwhile, girls are more inclined to express the feeling guilty and verbal aggression. However, boys are more inclined to hostility statistically reliably. According to the aggressiveness index, no statistically reliable difference was determined and it means aggressiveness is similar in the groups of boys and girls. We think the obtained conclusions could be applied more effectively with appropriate corrections, for example, by analysing concrete life situations of students.

Conflict of interest

The author declares that there is no conflict of interest.

References

- Šeibokaitė, L. (2008). *The changes of harmful behaviour towards self and others from 5th to 12th grades and psychosocial factors related to this behaviour*. Doctoral thesis. Kaunas: VDU. (in Lithuanian).
- Lloyd, C. B., Grant, M., & Ritchie, A. (2008). Gender differences in time use among adolescents in developing countries: Implications of rising school enrollment rates. *Journal of Research on Adolescence*, 18(1), 99-120. <https://doi.org/10.1111/j.1532-7795.2008.00552.x>
- Palujanskienė, A., & Uzdila, J. V. (2004). Aggression and conflict in the school of our days. *Pedagogy*, 73, 124-127. (in Lithuanian).
- ZinatMotlagh, F., Ataee, M., Jalilian, F., MirzaeiAlavijeh, M., Aghaei, A., & Shirazi, K. K. (2013). Predicting aggression among male adolescents: an application of the theory of planned behavior. *Health Promotion Perspectives*, 3(2), 269-275. <https://doi.org/10.5681/hpp.2013.031>
- Amadi, G. N., Ogadimma, M., & Taiwo, O. (2015). Influence of personality and demographic factor on aggressive behaviour among secondary school adolescents. *British Journal of Psychology Research*, 3(1), 1-6.
- Jiménez, T. I., & Estévez, E. (2017). School aggression in adolescence: Examining the role of individual, family and school variables. *International Journal of Clinical and Health Psychology*, 17(3), 251-260. <https://doi.org/10.1016/j.ijchp.2017.07.002>
- Barkauskaitė, M. (2001). *Teenagers: sociopedagogic dynamics*. Vilnius: VPU. (in Lithuania).
- Olivier, T. (2003). Aggressive adolescent behaviour in privileged schools. *Acta Academica*, 35(2), 103-126.

- Hopkins, L., Taylor, L., Bowen, E., & Wood, C. (2013). A qualitative study investigating adolescents' understanding of aggression, bullying and violence. *Children and Youth Services Review*, 35(4), 685-693. <https://doi.org/10.1016/j.childyouth.2013.01.012>
- Farrell, A. D., Thompson, E. L., & Mehari, K. R. (2017). Dimensions of peer influences and their relationship to adolescents' aggression, other problem behaviors and prosocial behavior. *Journal of Youth and Adolescence*, 46, 1351-1369. <https://doi.org/10.1007/s10964-016-0601-4>
- Wade, L., Smith, J. J., Duncan, M. J., & Lubans, D. R. (2018). Mediators of aggression in a school-based physical activity intervention for low-income adolescent boys. *Mental Health and Physical Activity*, 14, 39-46. <https://doi.org/10.1016/j.mhpa.2017.12.006>
- Yanagida, T., Strohmeier, D., & Spiel, C. (2019). Dynamic change of aggressive behavior and victimization among adolescents: Effectiveness of the ViSC program. *Journal of Clinical Child & Adolescent Psychology*, 48(sup1), S90-S104. <https://doi.org/10.1080/15374416.2016.1233498>
- Trajković, N., Pajek, M., & Bogataj, Š. (2020). Reducing aggression and improving physical fitness in adolescents through an after-school volleyball program. *Frontiers in Psychology*, 11, 575435. <https://doi.org/10.3389/fpsyg.2020.02081>
- Boulton, M. J., & Underwood, K. (1993). Bully/victim problems among middle school children. *European Education*, 25(3), 18-37. <https://doi.org/10.2753/EUE1056-4934250318>
- Owens, L. D., & MacMullina, C. E. (1995). Gender differences in aggression in children and adolescents in South Australian schools. *International Journal of Adolescence and Youth*, 6(1), 21-35. <https://doi.org/10.1080/02673843.1995.9747776>
- Björkqvist, K. (2018). Gender differences in aggression. *Current Opinion in Psychology*, 19, 39-42. <https://doi.org/10.1016/j.copsyc.2017.03.030>
- Jančiauskas, R. (2018). Senior pupils' behavioural difficulties at school. *Sport Science*, 3-4(93-94), 3-16. (in Lithuanian). <http://doi.org/10.15823/sm.2018.20>
- Österman, K., Björkqvist, K., Lagerspetz, K. M., Kaukiainen, A., Landau, S. F., Frączek, A., & Caprara, G. V. (1998). Cross-cultural evidence of female indirect aggression. *Aggressive Behavior: Official Journal of the International Society for Research on Aggression*, 24(1), 1-8. [https://doi.org/10.1002/\(SICI\)1098-2337\(1998\)24:1<1::AID-AB1>3.3.CO;2-F](https://doi.org/10.1002/(SICI)1098-2337(1998)24:1<1::AID-AB1>3.3.CO;2-F)
- Card, N. A., Stucky, B. D., Sawalani, G. M., & Little, T. D. (2008). Direct and indirect aggression during childhood and adolescence: A meta-analytic review of gender differences, intercorrelations, and relations to maladjustment. *Child Development*, 79(5), 1185-1229. <https://doi.org/10.1111/j.1467-8624.2008.01184.x>
- Chung, J. E., Song, G., Kim, K., Yee, J., Kim, J. H., Lee, K. E., & Gwak, H. S. (2019). Association between anxiety and aggression in adolescents: a cross-sectional study. *BMC Pediatrics*, 19, 1-9. <https://doi.org/10.1186/s12887-019-1479-6>
- Žukauskienė, R. (1999). Physical, verbal, and indirect aggression: gender differences. *Psychology*, 19, 98-107. (in Lithuania). <https://doi.org/10.15388/Psichol.1999.4440>
- Shaikh, F., Viveki, R. G., & Halappanavar, A. B. (2014). Physical and verbal aggressive behavior pattern among school children in urban area of North Karnataka: a cross sectional study. *Journal of Krishna Institute of Medical Sciences*, 3(2), 55-62.
- Gudžinskienė, V., & Burvytė, S. (2017). Lack of positive socialisation as a precondition for adolescent aggression. *Towards research-based education an edition collection of research studies*, 449-469. (in Lithuanian).
- Vassar, M., & Hale, W. (2009). Reliability reporting across studies using the Buss Durkee Hostility Inventory. *Journal of Interpersonal Violence*, 24(1), 20-37. <https://doi.org/10.1177/0886260508314931>
- Amedahe, F. K., & Owusu-Banahene, N. O. (2007). Sex differences in the forms of aggression among adolescent students in Ghana. *Research in Education*, 78(1), 54-64. <https://doi.org/10.7227/RIE.78.5>
- Crick, N. R., & Werner, N. E. (1998). Response decision processes in relational and overt aggression. *Child Development*, 69, 1630-1639. <https://doi.org/10.1111/j.1467-8624.1998.tb06181.x>
- Wakoli, C., Kiptiony, G., Chemwei, B., & Chonge, H. (2016). Peer influence on aggressive behaviour of adolescents in secondary schools in Bungoma County. *International Journal of Arts Humanities and Social Science*, 1(3), 59-66.
- Archer, J., Pearson, N. A., & Westeman, K. E. (1988). Aggressive behaviour of children aged 6-11: Gender differences and their magnitude. *British Journal of Social Psychology*, 27(4), 371-384. <https://doi.org/10.1111/j.2044-8309.1988.tb00839.x>
- Rozzaqyah, F., Silvia, A. R., & Wisma, N. (2021). Aggressive behavior: Comparative study on girls and boys in the middle school. In *4th Sriwijaya University Learning and Education International Conference (SULE-IC 2020)*, pp. 416-420. Atlantis Press. <https://doi.org/10.2991/assehr.k.201230.139>
- Moretti, M. M., Holland, R., & McKay, S. (2001). Self-other representations and relational and overt aggression in adolescent girls and boys. *Behavioral Sciences & The Law*, 19(1), 109-126. <https://doi.org/10.1002/bsl.429>
- Jančiauskas, R. (2018a). Aggression among athletic and non-athletic senior pupils. *Pedagogy*, 131(3), 153-171. (in Lithuanian). <https://doi.org/10.15823/p.2018.40>

Визначення особливостей агресивної поведінки учнів на заняттях з фізичного виховання

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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., 3 рис., 31 джерело.

Історія питання. Останнім часом особлива увага приділяється шкільному середовищу, де агресивна поведінка учнів, яка швидко поширюється, набуває все більш яскравих контурів і відображає процеси, що відбуваються в сучасному суспільстві та їх наслідки для молодого покоління. Вона часто може мати різні короткострокові та довгострокові наслідки для поведінки учня, його спілкування з оточуючими, емоційного стану та самооцінки. Таким чином, ця складна ситуація спонукає все частіше цікавитися причинами агресивної поведінки студентів та особливостями її прояву.

Мета дослідження – виявити особливості прояву агресивної поведінки учнів на уроках фізичної культури в аспекті віку та статі.

Матеріал і методи. У дослідженні взяли участь 197 учнів, з них 52 дівчинки 12-13 років і 44 хлопчики та 60 дівчаток і 41 хлопчик 14-15 років.

Результати. Результати дослідження показали, що 14-15-річні учні у порівнянні з 12-13-річними учнями більш схильні до таких форм агресивної поведінки на уроках фізичної культури, як негативізм, образа, роздратування, фізична та вербальна агресія. Також було визначено, що старші школярі характеризуються статистично достовірно вищими показниками ворожості та агресивності, ніж молодші. При аналізі агресивної поведінки учнів у гендерному аспекті було виявлено, що хлопці частіше проявляють такі форми агресивної поведінки, як негативізм, образа, роздратування та фізична агресія, тоді як дівчата більш схильні до почуття провини та вербальної агресії. Вища ворожість більш характерна для хлопців, ніж для дівчат, але агресивність у групах хлопців і дівчат за індексом агресивності оцінювалася однаково.

Висновки. Вважаємо, що отримані результати можуть бути більш ефективно застосовані при подальшому аналізі, наприклад, при аналізі конкретних життєвих ситуацій студентів.

Ключові слова: агресивна поведінка, форми агресивної поведінки, студенти, урок фізичної культури.

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Analyzing the Musculoskeletal Flexibility in Young Females: The Impact of a Six-Week Surya Namaskar Intervention on Back Flexibility and Lumbar Flexion

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Abstract

Objectives. This study aimed to investigate the effects of a structured six-week Surya Namaskar (Sun Salutation) regimen on back flexibility and lumbar flexion in female college students.

Materials and methods. Thirty female college students from the Gwalior District participated in the study and were randomly assigned to either an experimental group (Surya Namaskar regimen) or a control group. Baseline measurements of age, height, weight, and initial flexibility were recorded. The experimental group engaged in a six-week Surya Namaskar program, while the control group maintained their regular activities. Back flexibility and lumbar flexion were assessed using standardized tests before and after the intervention period.

Results. Statistical analysis revealed significant improvements in back flexibility and lumbar flexion in the experimental group following the six-week Surya Namaskar regimen. Specifically, the experimental group demonstrated a substantial increase in both back flexibility (mean change $\pm$ SD: 3.20 ± 0.95 cm) and lumbar flexion (mean change $\pm$ SD: 1.50 ± 0.75 cm), whereas the control group showed no significant changes in these parameters.

Conclusion. The findings underscore the effectiveness of Surya Namaskar in enhancing musculoskeletal flexibility among female college students. Integrating Surya Namaskar into educational programs could potentially benefit physical health by improving back flexibility and lumbar flexion, thus supporting overall musculoskeletal health and reducing the risk of injuries. Further research could examine the long-term effects and mechanisms underlying these improvements across diverse populations.

Keywords: Surya Namaskar, back flexibility, lumbar flexion, female college students, yoga practice.

Introduction

Yoga has become a popular form of exercise among college students in recent years, with a growing body of research (Xu et al., 2011) demonstrating its potential benefits for physical and mental health (Tripathi et al., 2018). Over the past few decades, yoga has gained significant popularity in the West, with increasing integration into the healthcare system (Yatham et al., 2023). Various traditions and schools of yoga exist, each with its unique philosophy and approach (Joshi, 1965). Several studies have examined the effects of yoga on college students, with positive results reported in

areas such as stress reduction, improved body composition, and enhanced overall well-being. One specific aspect of yoga that has received attention is the practice of Surya Namaskar, or Sun Salutation, a sequence of 12 asanas (yoga postures) commonly performed as a warm-up or stand-alone practice (Bertschinger et al., 2007). Physical education has been integral to ancient cultures, including those in the Indian subcontinent, since ancient times. These programs encompassed various aspects such as health, motor skills, military training, sports and recreational activities, medical therapy, physical rehabilitation, and spiritual growth. The practice of yogic asanas, or physical postures, is believed to have originated in the Harappan civilization, evidenced by the discovery of statues and seals depicting figures in yoga-like poses (Rao et al., 2013). Yoga is believed to have

begun between 4,000 to 8,000 years ago in the northwest Indian area of the Indus Valley civilization. Yoga is a conventional discipline that seeks to enhance an individual's physical, mental, emotional, and spiritual state of being (Ross & Thomas, 2010). The word "yoga" originates from the Sanskrit root "yuj," which means to join, yoke, or unite. This concept emphasizes the union of the individual self with the universal consciousness, aiming for a harmonious and balanced state of being (Feuerstein, 2002). The practice of yoga encompasses various physical, mental, and spiritual disciplines designed to achieve this state of unity (Iyengar, 1979). Yoga is the practice that combines the physical, mental, and spiritual aspects of a person by addressing the underlying conflicts present in all aspects of life (Oliver, 2005). Over time, publications in the disciplines of physiology and medicine started incorporating the concepts and practices of yoga (Khalsa et al., 2016). Surya Namaskara is a customary yoga pose meant to honor the Sun and is also referred to as Surya Namaskar or Sun Salutation. The renowned "Patanjali" and his or her followers developed this specific breathing and posture regimen thousands of years ago. It has since become an integral part of yoga practice, serving as a physical and spiritual exercise that not only strengthens the body but also calms the mind (Venkatesh & Vandhana, 2022, Omkar, 2012). The practice of Surya Namaskar, meaning "salutation to the sun," is believed to stimulate the Manipura Chakra, a key energy center located in the solar plexus region, which is associated with self-esteem, willpower, and personal transformation (Malhotra, 2017). By coordinating the movement of the body with the rhythm of the breath, Surya Namaskar is said to purify subtle energy channels and promote a deep sense of relaxation and mental clarity (Javadekar & K, 2012). The Surya Namaskar asanas are characterized by precise breathing patterns. Mental lucidity, physical stamina, and flexibility are all provided by it, in addition to revitalizing every cell in the body (Saraswati, 1983). A sequence of twelve asanas Surya Namaskar is composed of (postures). These alternating backward and forward movements profoundly extend the entire body forward bending postures, which contract and extend the spinal column to its utmost extent (Nandar, & Raj, 2014). Reduced flexibility can have significant implications for an individual's overall health and well-being. A sedentary lifestyle, physical inactivity, or fat accumulation around the joints that limits the full range of motion are some of the primary contributing factors to decreased flexibility (McPhail, 2015, King & King, 2010, Park et al., 2020, Reid, 2018). Lifestyle choices are crucial to an individual's flexibility (Micheo et al., 2012). A sedentary lifestyle, characterized by prolonged periods of inactivity, can lead to a decline in muscular flexibility and joint mobility (Walsh, 2011). Conserving the body's flexibility might potentially help alleviate the rigidity and tension that can lead to chronic and often fatal medical conditions. Surya Namaskar has profound effects on the body, allowing it to independently alter its kinanthropometric and physiological characteristics. The purpose of this study was to determine the degree to which the practice of Suryanamaskar affected the lumbar flexion and back flexibility of young adult men in college. It is hypothesized that engaging in a six-week Surya Namaskar regimen will lead to significant improvements in back flexibility and lumbar flexion. This study aims to

investigate the impact of a structured Surya Namaskar routine on these parameters in a cohort of thirty college women over a consecutive six-week period. Specifically, we propose that the consistent practice of Surya Namaskar will result in measurable enhancements in both back flexibility and lumbar flexion among the participants.

Materials and Methods

Study Participants

Thirty Female college students from the Gwalior District were selected to participate in this study. These participants were randomly assigned to one of two groups: an experimental group, which engaged in the Surya Namaskar regimen, and a control group, which did not partake in the regimen. Detailed characteristics of the participants, including age, height, weight, and initial flexibility measurements, are presented in Table 1. Before the study commenced, participants were provided with comprehensive information regarding the research, including its potential benefits and any associated risks. This briefing was conducted to ensure informed consent and to allow participants to make an educated decision about their involvement. Each participant underwent a thorough medical examination by a qualified physician to confirm their fitness for the study. All participants were deemed healthy and capable of safely engaging in the exercise regimen. The study was conducted in strict accordance with the guidelines of the Declaration of Helsinki, ensuring ethical standards were maintained throughout the research process. This adherence underscores our commitment to the ethical treatment and well-being of all participants.

Study Organization

This investigation employed an experimental approach with a two-group pretest-posttest design. The treatment group (n = 15) engaged in a six-week regimen of practicing Surya Namaskar, while Group II served as the control group (n = 15).

Table 1. Participants Characteristics (Mean $\pm$ SD)

Characteristics	SNP (G1) (n = 15)	Control (G2) (n = 15)
Age (years)	20.80 $\pm$ 0.52	20.90 $\pm$ 0.60
Height (cm)	162.40 $\pm$ 3.81	162.50 $\pm$ 3.90
Weight (kg)	60.10 $\pm$ 4.56	60.30 $\pm$ 4.30
BMI (kg/m ²)	22.82 $\pm$ 1.25	22.88 $\pm$ 1.37

Note: SNP (G1) refers to the group practicing the Surya Namaskar regimen, while Control (G2) refers to the group not participating in the regimen. The values represent mean measurements with standard deviations (SD) indicating variability within each group

Participants provided informed consent before the study commenced, with the assurance that they could withdraw at any time if they experienced discomfort during the training programs. All participants were eligible for inclusion based on their lack of musculoskeletal, neurological, or orthopedic disorders that could impair their ability to perform physical fitness tests or practice Surya Namaskar. No participants dropped out of the study. The study procedures were

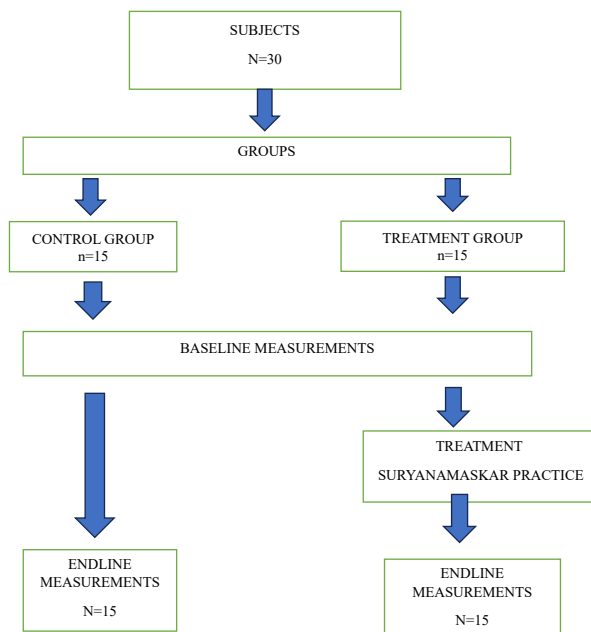


Fig. 1. Flow Diagram

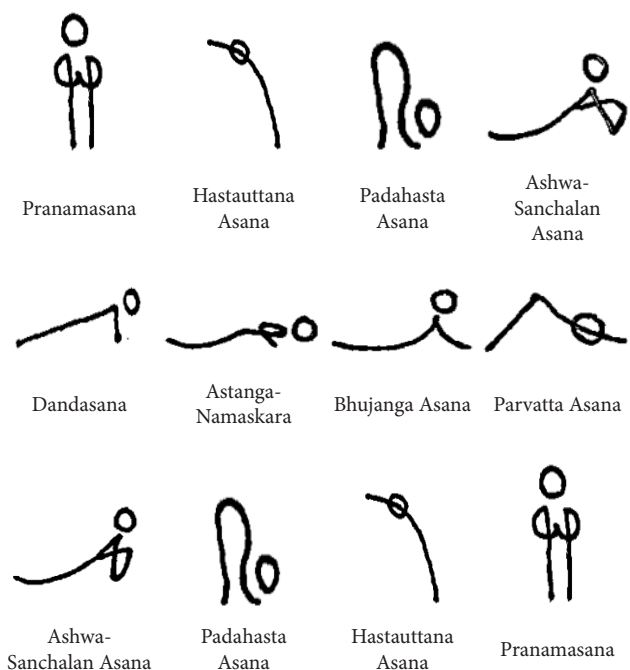


Fig 2. Diagram

conducted by ethical standards outlined in the 1964 Helsinki Declaration and its subsequent amendments. Standard protocols were utilized to assess the parameters of interest. Before testing, participants completed a warm-up consisting of a five-minute low-intensity aerobic run followed by ten minutes of active and passive stretching of the upper and lower extremity muscles. These protocols ensured participants were adequately prepared for the experimental procedures. This structured approach aimed to minimize variability and ensure rigorous adherence to ethical guidelines and scientific standards throughout the study.

Anthropometric Measurements

Anthropometric measurements were conducted using a portable digital scale with a weight precision of 0.1 kilograms, and height was measured using a tape measure. The Body Mass Index (BMI) is calculated by dividing weight (in kilograms) by height (in meters squared). 12 poses are executed without disruption with each pose lasting 12 seconds. Commence with 7 cycles and increase by one every two weeks.

Sit and Reach Test

Participants were instructed to do the sit-and-reach test, a highly reliable assessment method well-recognized for its accuracy. The chair sit and reach test has shown strong interclass correlation coefficient (ICC) values ranging from 0.92 to 0.96, as (Jones et al. 1998) reported. Similarly, the back-saver sit and reach test has shown an ICC value of 0.99, according to (Patterson et al. 1996). This test aimed to assess the pliability of the lumbar region and the muscles at the back of the thigh. Before assuming a seated position with their feet uncovered, legs extended, and soles resting flat on a horizontal cross board, the participants engaged in a series of mild stretching exercises to gradually lengthen

Table 2. Training protocol

Protocol Description	Duration
Warm-up & Conditioning	5-12 mins
Joint stretching and rotation	
Suryanamaskar	
Step 1: Hasta uttanasan (Raised Arms Pose)	
Step 2: Padhahastasan (Hand to Foot Pose or Standing Forward Bend)	
Step 3: Ekapadaprasaranasana (Equestrian Pose or Low Lunge)	
Step 4: Dwipadaprasaranasana (Stick Pose or Plank Pose)	
Step 5: Sasankasana (Rabbit Pose or Moon Pose)	
Step 6: Ashtanga Namaskar (Eight Limbed Pose or Salute with Eight Limbs)	12-15 mins
Step 7: Bhujangasan (Cobra Pose)	
Step 8: Parvatasan (Downward Facing Dog Pose or Mountain Pose)	
Step 9: Sasankasana (Rabbit Pose or Moon Pose)	
Step 10: Ekapadaprasaranasana (Equestrian Pose or Low Lunge)	
Step 11: Padhastasan (Hand to Foot Pose or Standing Forward Bend)	
Step 12: Hasta uttanasan (Raised Arms Pose)	
Warm down	
Technique for deep relaxation	5-7 mins
Closing Prayer	
Ohm Shanti Shanti Shanti	10 secs

Additional Notes – The pose is held for 6 seconds without a break. Begin with 4 cycles and increase by one every two weeks

their muscles. They smoothly advanced while using their fingers to slide a marker along a scale until it reached the maximum position, which they maintained for a duration of two seconds. To provide a reliable and accurate assessment of flexibility throughout the study, this measurement was conducted twice, and the maximum distance achieved was recorded to the nearest 0.5 cm. Both of these measures were obtained while keeping the knee straight.

Schober Test

The lumbar flexion was assessed in this specific inquiry utilising the latest iteration of the Schober test. Initially, the level of S2 was established and recorded precisely at the midpoint between the two PSISs (posterior superior iliac spines), which are the indentations seen in the pelvis. Additional marks were created 5 cm below the S2 level and 10 centimetres above it. Subsequently, the individuals were instructed to flex their bodies forward, and further measurements were conducted to ascertain the gap between the lower and upper indicators. White and (Norkin 2011) used the difference between these two values to estimate the extent of lumbar spine bending throughout the test. The study's findings were made more reliable by using a standardized approach, which ensured that all participants got a precise and consistent assessment of their lumbar flexibility.

The Yoga Intervention Protocol

Following the pre-test, the intervention group was given a one-hour teaching session to teach them whatever they needed to know. the primary positions that make up the suryanamaskar technique. It was specified to the participants that they should breathe naturally. When you want to follow the natural breath, you should concentrate on each inhalation and exhalation for the period that has been established. The individuals were asked to maintain each posture throughout the practice for the length of one inhalation, or exhale, depending on the activity that they were doing. In addition, they were provided with an internet video of a trained yoga teacher doing suryanamaskar, which was intended to assist them in comprehending the practice. Additionally, they were provided with an internet video of a trained yoga teacher performing suryanamaskar, which was designed to aid them in understanding the practice.

Statistical Analysis

The data analysis in this study comprised two primary components. First, the Shapiro-Wilk test was employed to assess the normality of the data distribution, a prerequisite for subsequent statistical tests. Following confirmation of normality, a paired sample t-test was conducted to evaluate the hypotheses. Specifically, this test aimed to compare the outcomes of pretest and post-test measurements within the same group. IBM SPSS Statistics 26 software (SPSS, Inc., Chicago, IL, USA) was utilized for all statistical analyses, ensuring robust and precise handling of the data. This methodological approach enabled a comprehensive examination of the effects of the intervention on the study outcomes while adhering to established statistical standards.

Result

The six-week study comprised 30 days of practice, including one pretest, 28 treatment sessions, and one post-test. Up to fifteen female college students participated in the study. The primary findings focused on the measurements of lumbar flexion and overall back flexibility, derived from these sessions.

The pretest and post-test results for both the treatment and control groups were evaluated using the Shapiro-Wilk test, as shown in Table 2. Each value obtained was ≥ 0.05 ,

Table 3. Normality Test

Groups	Variable	Tests	Shapiro-Wilk
EG	Back flexibility	Pre	0.92
		Post	0.93
	Lumbar Flexion	Pre	0.90
		Post	0.89
CG	Back flexibility	Pre	0.91
		Post	0.90
	Lumbar Flexion	Pre	0.89
		Post	0.90

indicating that the data were normally distributed. Given the normal distribution of the data, as confirmed by the Shapiro-Wilk test, we proceeded to use the paired sample t-test for hypothesis testing. This parametric statistical method allowed for a detailed comparison of pretest and post-test outcomes within each group, enabling us to accurately assess the impact of the Surya Namaskar regimen on back flexibility and lumbar flexion.

Table 4. Paired Sample T-Test

Variables	Group	Test	Mean $\pm$ SD	t	Sig. 2-tailed
BF	CON	Pre	31.10 $\pm$ 0.90	1.32	0.175
		Post	30.95 $\pm$ 0.85		
	EXP	Pre	31.30 $\pm$ 1.05	16.45*	0.000
		Post	34.30 $\pm$ 1.00		
LF	CON	Pre	6.50 $\pm$ 0.80	0.18	0.845
		Post	6.55 $\pm$ 0.88		
	EXP	Pre	7.00 $\pm$ 1.25	3.95*	0.001
		Post	8.50 $\pm$ 0.90		

* Statistically significant difference, mean scores at point comparisons from baseline: sig (2-tailed) value of ≤ 0.05 ; data are presented as means $\pm$ SD

Table 4 indicates that in the treatment group, the obtained 't' values for the variables were 16.45 (Back Flexibility) and 3.95 (Lumbar Flexion). These values were found to be statistically significant at the 0.05 level of confidence for degrees of freedom 1 and 14, as they were higher than the minimum table value of 2.14. Conversely, the obtained t ratios between pre- and post-test in the control group were 1.32 (Back Flexibility) and 0.18 (Lumbar Flexion), which

were less than the necessary table value of 2.14 and were found to be not statistically significant.

Discussion

This study evaluates the impact of a six-week course of Surya Namaskar practice on lumbar flexion and back flexibility in female college students. According to our findings, Surya Namaskar's practice significantly improved both back flexibility and lumbar flexion in these students. Previous research also supports the positive effects of Surya Namaskar on important kinanthropometric parameters. Time constraints are often cited as a barrier to regular exercise; however, Surya Namaskar, a sequence of twelve yoga postures, can be an efficient and time-saving way to improve physical fitness (Javadekar & K, 2012). According to our findings, Surya Namaskar's practice significantly improved both back flexibility and lumbar flexion in these students. Previous research also supports the positive effects of Surya Namaskar on important kinanthropometric parameters (Xu et al., 2011, Tripathi & Bharadwaj, 2013, Sarkar, 2022). For individuals facing such challenges, incorporating Surya Namaskar, or the "salute to the sun," into their daily routine can be an ideal solution (Saraswati, 2004). Flexibility is crucial for performing daily tasks efficiently, and variations in flexibility can lead to biomechanical changes in joints and altered postures. Our results align with previous studies that reported significant improvements in back and lumbar flexibility due to Surya Namaskar's practice. For instance, a study comparing the effects of Surya Namaskar and dynamic stretching on hamstring flexibility in physiotherapy students found Surya Namaskar to be more effective in enhancing flexibility (Mangaonkar et al., 2018). Similarly, Sisodia (2017) observed notable improvements in flexibility among participants practicing Surya Namaskar. The statistical analysis in our study showed significant changes in the treatment group compared to the control group. The experimental group demonstrated a substantial increase in back flexibility ($t = 16.45$, $p = 0.000$) and lumbar flexion ($t = 3.95$, $p = 0.001$). In contrast, the control group did not show significant changes in either back flexibility ($t = 1.32$, $p = 0.175$) or lumbar flexion ($t = 0.18$, $p = 0.845$). These findings suggest that Surya Namaskar's practice can lead to significant improvements in flexibility, which are essential for maintaining a range of motion and preventing injuries. Such physiological effects may explain the observed improvements in back flexibility and lumbar flexion among the experimental group (Sarkar, 2022). A study examined the impact of a six-week Surya Namaskar program on back flexibility and lumbar flexion in male college students. Results showed significant improvements in both measures compared to the control group, suggesting Surya Namaskar's potential to enhance musculoskeletal health in this population. They recommend integrating this practice into educational curricula for its physical benefits (Balaji et al., 2024). In previous studies, experimental group demonstrated significant improvements in both back flexibility ($t(DF) = 16.45$, $p < 0.001$; (Venkatesh & Vandhana, 2022; Sarkar, 2022) and lumbar flexion ($t(DF) = 3.95$, $p = .001$; Javadekar & K, 2012; Sarkar, 2022; Venkatesh & Vandhana, 2022). These findings suggest that the intervention implemented effectively enhanced participants' ability to flex their spine and lumbar region. These

findings suggest that Surya Namaskar practice can lead to significant improvements in flexibility, which are essential for maintaining a range of motion and preventing injuries. Previous research has speculated that Surya Namaskar can be an ideal aerobic exercise, involving both static stretching and slow dynamic components, which may contribute to enhanced flexibility. Some studies have also found that Surya Namaskar can have a positive impact on cardiovascular and metabolic responses, with participants exercising at up to 90% of age-predicted maximal heart rate during the practice (Javadekar & K, 2012). Surya Namaskar has been shown to enhance general health and fitness and provides benefits in both asana and pranayama (Borker & Pednekar, 2003). Research by (Singh et al. 2010) indicated that Surya Namaskar significantly enhances hamstring flexibility and muscular endurance. Moreover, (Fondran, 2008) demonstrated that Surya Namaskar improves muscle endurance, upper body strength, and hamstring flexibility. During Surya Namaskar, the superficial back line contracts in sync with the superficial front line, enhancing overall muscle coordination. Unlike dynamic stretching, which targets specific muscles and joints, Surya Namaskar strengthens all the muscles in the back, including the smaller ones along the spinal column. This practice stimulates blood circulation in the vertebral region, benefiting the nerves there. The practice of Surya Namaskar, which translates to "salutation to the sun", is a sequence of twelve postures that integrate physical movement, breath control, and mental focus. Existing research suggests that this holistic practice can elicit a range of physiological benefits, from enhancing cardiovascular function to boosting metabolic rate and respiratory capacity. The practice of Surya Namaskar, which translates to "salutation to the sun," is a sequence of twelve postures that integrate physical movement, breath control, and mental focus. Existing research suggests that this holistic practice can elicit a range of physiological benefits, from enhancing cardiovascular function to boosting metabolic rate and respiratory capacity (Sarkar, 2022). The holistic benefits of Surya Namaskar extend far beyond just the physical realm. A study also revealed Aging is another significant factor that can contribute to reduced flexibility (Murray et al., 2023). The practice has been shown to improve cardiovascular endurance and flexibility, two key factors that can enhance an individual's overall physical performance and well-being (Malhotra, 2017). Besides improving hamstring flexibility, Surya Namaskar helps maintain the flexibility of the spine, contributing to overall physical health. Based on the findings of this research, incorporating Surya Namaskar practice into the routine of female college students can significantly improve back flexibility and lumbar flexion, supporting better posture and physical health. These results reinforce the notion that Surya Namaskar is a beneficial practice for enhancing flexibility and overall fitness in college students.

Conclusion

This study aimed to investigate the effects of a structured six-week Surya Namaskar (Sun Salutation) regimen on back flexibility and lumbar flexion in female college students. The findings reveal significant improvements in both back flexibility and lumbar flexion among participants who practiced Surya Namaskar compared to those in the control

group. Specifically, the experimental group demonstrated a substantial increase in back flexibility and lumbar flexion whereas the control group showed no significant changes in either parameter. These results underscore the effectiveness of Surya Namaskar as a means to enhance musculoskeletal flexibility, which is crucial for maintaining optimal physical health and preventing injuries. The positive outcomes observed align with previous research indicating that Surya Namaskar contributes to improved kinanthropometric parameters. The practice integrates elements of static stretching and slow dynamic movements, potentially explaining its efficacy in enhancing flexibility. Moreover, Surya Namaskar's holistic approach, which combines physical postures, breath control, and mental focus, may contribute to its broader physiological benefits, including cardiovascular enhancement and metabolic efficiency. Our findings contribute to the growing body of evidence supporting the incorporation of Surya Namaskar into physical fitness routines, particularly for young adults in educational settings. By improving back flexibility and lumbar flexion, this practice can help individuals maintain proper posture, reduce the risk of musculoskeletal disorders, and promote overall well-being. Future studies could explore the long-term effects of Surya Namaskar across diverse populations and further investigate its mechanisms of action on flexibility and other health-related parameters. Surya Namaskar emerges as a beneficial practice for enhancing flexibility and supporting musculoskeletal health among college students. Its integration into educational and fitness programs could offer substantial benefits for physical fitness and overall health promotion.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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References

- Xu, L., Zhang, W., & Han, J. J. (2011, February 1). Study on the Effects of Yoga on Female College Students' Physical and Mental Health. *Trans Tech Publications*, 187, 164-168. <https://doi.org/10.4028/www.scientific.net/amr.187.164>
- Tripathi, M N., Kumari, S., & Ganpat, T S. (2018, January 1). Psychophysiological effects of yoga on stress in college students. *Medknow*, 7(1), 43-43. https://doi.org/10.4103/jehp.jehp_74_17
- Yatham, P., Chintamaneni, S., & Stumbar, S E. (2023, August 14). *Lessons From India: A Narrative Review of Integrating Yoga Within the US Healthcare System*. Cureus, Inc. <https://doi.org/10.7759/cureus.43466>
- Joshi, K. (1965, January 1). On the Meaning of Yoga. *University of Hawaii Press*, 15(1), 53-53. <https://doi.org/10.2307/1397408>
- Bertschinger, D., Mendrinos, E., & Dosso, A. (2007, September 25). Yoga can be dangerous glaucomatous visual field defect worsening due to postural yoga. *BMJ*, 354(8000), 1413-1414. <https://doi.org/10.1136/bmj.2007.114546>
- Rao, N S K., Keshavan, M S., & Rao, T S. (2013, January 1). Yoga and mental health: Promising road ahead, but proceed with caution. *Medknow*, 55(7), 329-329. <https://doi.org/10.4103/0019-5545.116295>
- Ross, A., & Thomas, S. (2010). The Health Benefits of Yoga and Exercise: A Review of Comparison Studies. *The Journal of Alternative and Complementary Medicine*, 16(1), 3-12. <https://doi.org/10.1089/acm.2009.0044>
- Feuerstein, G. (2002). *The Yoga Tradition: Its History, Literature, Philosophy and Practice*. Hohm Press.
- Iyengar, B.K.S. (1979). *Light on Yoga*. Schocken Books.
- Borg Oliver, S. (2005). *Yoga synergy applied anatomy & physiology of yoga*, p.20.
- Khalsa, S.B.S., Cohen, L., McCall, T., & Telles, S., (2016). *The Principles and Practice of Yoga in Health Care*, Handspring Publishing Ltd.
- Prasanna Venkatesh, L., & Vandhana, S. (2022). Insights on Surya namaskar from its origin to application towards health. *Journal of Ayurveda and Integrative Medicine*, 13(2), 100530. <https://doi.org/10.1016/j.jaim.2021.10.002>
- Omkar, S N. (2012, January 1). Surya Namaskaar for Holistic Well Being: A Comprehensive Review of Surya Namaskaar. *OMICS Publishing Group*, 02(02). <https://doi.org/10.4172/2157-7595.1000e109>
- Malhotra, P. (2017, December 29). Surya namaskar: a way to relax the mind. *MedCrave Group*, 1(6). <https://doi.org/10.15406/smdij.2017.01.00028>
- Javadekar, P., & K, M M K. (2012, January 1). Effect of Surya Namaskar on Sustained Attention in School Children. *OMICS Publishing Group*, 2(2). <https://doi.org/10.4172/2157-7595.1000110>
- Saraswati, S. (1983). *Surya Namaskar-A technique of solar vitalization*, Munger Yoga Publications Trust, Munger, Bihar, India.
- Siddappa Nandar., & Sundar Raj, Urs. (2014). Influence of suryanamaskar on human body. *Academic Sports Scholar*, 3(7).
- McPhail, S. (2015). Multi-morbidity, obesity and quality of life among physically inactive Australians accessing physiotherapy clinics for musculoskeletal disorders. *Physiotherapy*, 101, e986-e987. <https://doi.org/10.1016/j.physio.2015.03.1846>
- King, A. C., & King, D. K. (2010). Physical Activity for an Aging Population. *Public Health Reviews*, 32(2), 401-426. <https://doi.org/10.1007/BF03391609>
- Park, J H., Moon, J., Kim, H J., Kong, M H., & Oh, Y H. (2020, November 20). Sedentary Lifestyle: Overview of Updated Evidence of Potential Health Risks. *Korean Academy of Family Medicine*, 41(6), 365-373. <https://doi.org/10.4082/kjfm.20.0165>
- Reid, M C. (2018, June 29). Sensitivity to Physical Activity: Identifying Important Predictors and Outcomes in Pain-Free Older Adults Using a Simple Activity-Related Measure. *Oxford University Press*, 19(8), 1512-1513. <https://doi.org/10.1093/pm/pny130>
- Micheo, W., Baerga, L., & Miranda, G. (2012). Basic Principles Regarding Strength, Flexibility, and Stability Exercises. *PM&R*, 4(11), 805-811. <https://doi.org/10.1016/j.pmrj.2012.09.583>

- Walsh, R. (2011, January 1). Lifestyle and mental health. *American Psychological Association*, 66(7), 579-592. <https://doi.org/10.1037/a0021769>
- Jones, C. J., Rikli, R. E., Max, J., & Noffal, G. (1998). The reliability and validity of a chair sit-and-reach test as a measure of hamstring flexibility in older adults. *Research quarterly for exercise and sport*, 69(4), 338-343. <https://doi.org/10.1080/02701367.1998.10607708>
- Patterson, P., Wiksten, D. L., Ray, L., Flanders, C., & Sanphy, D. (1996). The validity and reliability of the back saver sit-and-reach test in middle school girls and boys. *Research quarterly for exercise and sport*, 67(4), 448-451. <https://doi.org/10.1080/02701367.1996.10607976>
- Norkin, C.C., & White, D.J. (2017) *Measurement of Joint Motion: A Guide to Goniometry*. 5th Edition, F. A. Davis Company, Philadelphia.
- Tripathi, M. K., & Bharadwaj, B. K. (2013). Effect of Pranayama & Yoga-Asana on Cognitive Brain Functions in Type 2 Alzheimer-P3 Event Related Evoked Potential (ERP). *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.2322399>
- Sarkar, D. (2022). Effect of Surya namaskar on selected physical fitness variables of physical education students. *AkiNik Publications*, 9(1), 425-427. <https://doi.org/10.22271/kheljournal.2022.v9.i1g.2412>
- Saraswati, S. (2004). *Surya Namaskar-A technique of solar vitalization* (2nd edition). Yoga Publications Trust, Mungar, Bihar, India, 3-5,12,18.
- Mangaonkar, A., & Puntambekar, A. (2018). Effect of suryanamaskar vs dynamic stretching on hamstring flexibility among physiotherapy students: a pilot study. *International Journal of Physiotherapy*, 5(6), 202-206. <https://doi.org/10.15621/ijphy/2018/v5i6/178058>
- Dr. Anurodh Singh Sisodia (2017). Effect of Suryanamaskar on flexibility of school girls. *Int J Phys Educ Sports Health*, 4(2), 154-156.
- Balaji, E., Murugavel, K., Rajkumar, M., Logeswaran, S., Vijayasankar, V., & Devaraj, C. (2024). The Effect of a Six-Week Course of Surya Namaskar Practice on Back Flexibility and Lumbar Flexion in Male College Students. *Physical Education Theory and Methodology*, 24(1), 41-46. <https://doi.org/10.17309/tmfv.2024.1.05>
- Borker, A. S., & Pednekar, J. R. (2003). Effect of pranayam on visual and auditory reaction time. *Indian journal of physiology and pharmacology*, 47(2), 229-230.
- Kanwaljeet, Singh & Bal, Baljinder & Wilfred, Vaz. (2010). The effect of suryanamaskar yogasana on muscular endurance and flexibility among intercollege yoginis. *Citius Altius Fortius*. 27.
- Fondran, K. M. (2008). *The effect of Surya Namaskara yoga practice on resting heart rate and blood pressure, flexibility, upper body muscle endurance, and perceived well-being in healthy adults* (Master's thesis). Cleveland State University. Retrieved from <https://engagedscholarship.csuohio.edu/etdarchive/550>
- Murray, K. O., Mahoney, S. A., Venkatasubramanian, R., Seals, D. R., & Clayton, Z. S. (2023). Aging, aerobic exercise, and cardiovascular health: Barriers, alternative strategies and future directions. *Experimental Gerontology*, 173, 112105. <https://doi.org/10.1016/j.exger.2023.112105>

Аналіз показників гнучкості опорно-рухового апарату у молодих осіб жіночої статі: Вплив шеститижневої інтервенції з виконання комплексу вправ йоги сур'я-намаскара на розвиток гнучкості спини та згинання поперекового відділу хребта

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

Реферат. Стаття: 8 с., 4 табл., 2 рис., 36 джерел.

Мета дослідження. Метою цього дослідження було вивчення впливу структурованого шеститижневого курсу з виконання комплексу вправ йоги сур'я-намаскара («Вітання Сонцю») на розвиток гнучкості спини та згинання поперекового відділу хребта у студенток коледжів.

Матеріали та методи. У дослідженні взяли участь тридцять студенток коледжу з округу Гваліор, які були рандомізовані до експериментальної групи (режим тренувань сур'я-намаскара) або до контрольної групи. У досліджуваних осіб було зафіксовано вихідні дані щодо віку, зросту, ваги та початкового рівня гнучкості. Експериментальна група виконувала програму комплексу вправ йоги сур'я-намаскара протягом шести тижнів, тоді як контрольна група дотримувалася своїх звичайних видів активності. Показники гнучкості спини та згинання поперекового відділу хребта оцінювали за допомогою стандартизованих тестів перед початком та після завершення періоду інтервенції.

Результати. Статистичний аналіз показав значне покращення рівня гнучкості спини та згинання поперекового відділу хребта в експериментальній групі після проведення шеститижневого курсу тренувань за методикою сур'я-намаскара. Зокрема, експериментальна група продемонструвала істотне збільшення як показників гнучкості спини (середня варіація $\pm$ SD: $3,20 \pm 0,95$ см), так і згинання поперекового відділу хребта (середня варіація $\pm$ SD: $1,50 \pm 0,75$ см), тоді як у контрольній групі не спостерігалось суттєвих змін у зазначених параметрах.

Висновок. Отримані результати підкреслюють ефективність застосування методики сур'я-намаскара з метою підвищення гнучкості опорно-рухового апарату серед студенток коледжів. Інтеграція комплексу вправ йоги сур'я-намаскара в освітні програми може потенційно сприяти вдосконаленню фізичного здоров'я шляхом поліпшення показників гнучкості спини та згинання поперекового відділу хребта, таким чином підтримуючи загальний стан здоров'я опорно-рухового апарату та зменшуючи ризик отримання травм. Подальші дослідження можуть бути спрямовані на вивчення довгострокових ефектів і механізмів, що лежать в основі таких покращень у різних групах населення.

Ключові слова: сур'я-намаскара, гнучкість спини, згинання поперекового відділу хребта, студентки коледжу, практика йоги.

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The Effect of Rhodiola Rosea on the Nuclear Factor Kappa-B and Tumor Necrosis Factor Alpha Levels after High Intensity Training

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Abstract

Objectives. This research aimed to analyze the effect of Rhodiola rosea on the Nuclear Factor Kappa B (NF-κB) and Tumor Necrosis Factor Alpha (TNF-α) levels after high-intensity training.

Materials and methods. The research was conducted using an experiment method with a pre-test and post-test group design. It involved 20 healthy males as participants. They were 19 years old on mean and currently enrolled as university students. The participants were purposively selected and divided into two groups. One group was administered a placebo (Age = 19.60 ± 0.69), while the other was assigned to a medication group that received Rhodiola rosea with a 500 mg dosage (Age = 19.30 ± 0.82). The study began by collecting data from the research subjects on the first day. After that, the participants were asked to warm up before doing high-intensity physical training composed of exercises such as walking lunges, good-mornings (also known as weight training exercises), and leg extensions. The training was performed for 4 sets, with a recovery period of 1 minute between the sets. The training intensity was monitored using a Polar H9 Heart Rate Sensor. On the second day (24 hours after the training session), blood samples were collected from all subjects. The data were treated as pre-test data in order to calculate the NF-κB and TNF-α levels. Subsequently, the participants were given a placebo and Rhodiola rosea intervention based on the predetermined groups. On the third day (48 hours after the training session), the subjects' blood samples were collected again. This time, blood collection was done following the training as post-test data. The next procedure included the blood sample analyzing in the laboratory using the ELISA method. Furthermore, SPSS software was used for the statistical analysis of this research.

Results. The findings of the study showed that there was no significant difference in serum NF-κB levels in the placebo group and there was a notable reduction in serum NF-κB levels in the Rhodiola rosea group. Additionally, a substantial decrease in serum TNF-α levels was observed in both groups.

Conclusions. To sum it up, giving Rhodiola rosea a 500 mg/day dosage potentially decreases the NF-κB level. Meanwhile, for the TNF-α, both groups reported a decrease of the serum level. Consequently, further research is recommended to investigate the effect of Rhodiola rosea on other inflammatory markers, including Interleukin-10 (IL-10) and Interleukin-1β (IL-1β), as well as muscle damage biomarkers, such as creatine kinase.

Keywords: rhodiola rosea, exercise-induced muscle damage, inflammation, health.

Introduction

Interval training with high intensity can increase physiological responses, such as muscle damage and delayed

muscle pain (Hung et al., 2021), which is typically caused by uncontrollable inflammatory processes (Amalraj, Divya, & Gopi, 2020). According to recent scholars, delayed muscle pain indicates increasing pro-inflammatory cytokines, like Tumor Necrosis Factor Alpha (TNF-α) (Novadri Ayubi et al., 2022). This increase is caused by transcription factors, such as Nuclear Factor Kappa B (NF-κB) (Zinatizadeh et

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al., 2021), which have been known to regulate inflammatory responses (Park & Hong, 2016).

To alleviate this pain, various types of medicines are actually available in the market (Ezike et al., 2023). One of them is a non-steroidal anti-inflammatory (NSAIDs), which are effective in reducing inflammation and pain (Mahesh, Anil Kumar, & Reddanna, 2021). Today, 30 million people have used NSAIDs to address this issue (Ayubi et al., 2022). In fact, continuous consumption of this medicine might affect their health and lead to drug dependence (Tsagareli et al., 2012).

For this reason, alternative medication is urgently required to address this issue. Of the alternative medications, there are some herbs that grow in the plateau, such as Rhodiola rosea (Ivanova, Stojcheva, & Quintela, 2022). Laboratory research indicated that this plant has anti-cancer, anti-oxidant, and anti-inflammation characteristics (Li et al., 2017; Bernatoniene, Jakstas, & Kopustinskiene, 2023). Currently, Rhodiola rosea is gaining popularity and has been used as a means to improve performance in sports. However, currently, its effects on transcription factors and inflammatory biomarkers after exercise are unknown. Therefore, this study aims to analyze the effect of Rhodiola rosea on NF-kB and TNF-a levels after high-intensity exercise.

Materials and Methods

Study Participants

This research employed a pre-test and post-test control group design. The research involved 20 healthy men who were enrolled as university students. On average, they were 19 years old who were selected a purposively. They were grouped into two: the placebo group (Age = 19.60 ± 0.69) and the group that received the Rhodiola rosea (Age = 19.30 ± 0.82).

Inclusion and exclusion criteria were determined to identify if the potential subjects could meet the requirements of this research. The inclusion criteria covered university students between 18 and 25 years old with a normal Body Mass Index (BMI), Normal BMI range 18.5-24.9). In addition, the students should not regularly do exercise. On the other hand, the exclusion criteria were those under 18 years old and who had abnormal blood pressure prior to training. Finally, subjects were dropped out (eliminated) if they consumed non-steroid anti-inflammatory drugs (NSAID).

Procedure

Data collection in this research involved several stages. Before it began, the subjects went through a screening process. The process was based on certain criteria that allow data to be included into or excluded from the analysis. They also provided informed consent showing their agreement to this research project. They were grouped into divided into two. One group was a placebo, and the other was the a medication group that received the Rhodiola rosea. The placebo took empty capsule, while the medication group took Rhodiola rosea with a 500mg dosage. Rhodiola rosea was used as a supplement.

Data collection begins on the first day by collecting data on subject characteristics such as collecting data on age, height,

weight, BMI and blood pressure. After that, the subjects performed a series of physical exercises for approximately one hour consisting of warm-up, core training and cool-down. Core exercises include high-intensity activities, such as walking lunges, good mornings, and leg extensions. This exercise is done in 4 sets with a 1 minute break (recovery) between sets. The training intensity was monitored using the Polar H9 Heart Rate Sensor. On day 2 or 24 hours after training, the subject's blood was collected as pre-test data to assess NF-kB and TNF-a data. Blood collection is carried out by medical personnel. The subjects were then given placebo or Rhodiola rosea treatments, depending on their assigned groups. On day 3, or 48 hours after training, another blood collection was done as post-test data. Next, the blood sample is then analyzed in the laboratory using the ELISA method. Blood samples were analyzed in the Airlangga University hospital laboratory. Finally, the researchers analyzed the data and made a written report as a form of responsibility.

ELISA Procedure

1. Add 100µL standard or sample to the wells. Incubate for 90 min at 37°C.
2. Discard the liquid, immediately add 100µL Biotinylated Detection Ab working solution to each well. Incubate for 60 min at 37°C.
3. Aspirate and wash the plate for 3 times.
4. Add 100µL HRP conjugate working solution. Incubate for 30 min at 37°C. Aspirate and wash the plate for 5 times.
5. Add 90µL Substrate Reagent. Incubate for 15 min at 37°C.
6. Add 50µL Stop Solution.
7. Read the plate at 450nm immediately. Calculation of the results.

Statistical Analysis

After collecting the data, a statistical analysis was done using the SPSS software. The data were analyzed descriptively to obtain the mean, standard deviation, and standard error. Further, the study performed a normality test was carried out using the Shapiro-Wilk. If the data spread normally, a difference test was calculated using the paired t-test method. However, if the results showed differently, the data were examined using the Wilcoxon signed-rank test.

Ethics

Prior to data collection, we have received ethical approval from the Health Research Ethics Committee of Medical Faculty, Ciputra University, with registration No.103/EC/KEPK/FKUC/III/2024.

Results

This section provides data that addresses the research objectives. First, it provides information about the participants' general characteristics in Table 1. These data allow us to better understand the characteristics of each group. The data are presented in mean $\pm$ standard deviation. The first analysis produced a t-test value where no significant

difference was found between the placebo and the *Rhodiola rosea* groups ($p \geq 0.05$).

Following that, another test was performed to examine the normality of data distribution in this research. Table 2 shows that the pre-test data for NF-kB and TNF- α levels given the placebo was not distributed normally ($p < 0.05$). The results of the NF-kB and TNF- α levels between pre-test and post-test are described in Figure 1.

Table 1. Participants' Characteristics

Data	Group Placebo	Group <i>Rhodiola Rosea</i>	P value
Age (y)	19.60 $\pm$ 0.69	19.30 $\pm$ 0.82	0.429
Height (cm)	167.00 $\pm$ 6.59	169.70 $\pm$ 6.53	0.290
Weight (kg)	62.36 $\pm$ 9.96	63.03 $\pm$ 6.82	0.874
BMI (kg/m ²)	22.22 $\pm$ 2.97	22.22 $\pm$ 2.80	0.721
Systolic (mmHg)	109.70 $\pm$ 9.32	118.60 $\pm$ 13.72	0.109
Diastolic (mmHg)	68.10 $\pm$ 6.98	73.90 $\pm$ 7.70	0.413

Table 2. Normality test results

Data	Group	Shapiro-Wilk	
		n	P-value
NF-kB Level (Pre-test)	Placebo	10	0.042
	<i>Rhodiola Rosea</i>	10	0.842
NF-kB Level (Post-test)	Placebo	10	0.161
	<i>Rhodiola Rosea</i>	10	0.537
TNF- α Level (Pre-test)	Placebo	10	0.204
	<i>Rhodiola Rosea</i>	10	0.136
TNF- α Level (Post-test)	Placebo	10	0.018
	<i>Rhodiola Rosea</i>	10	0.537

Table 3. NF-kB and TNF- α levels test results

Different Test Methods	Group (pre-test and post test)	P-value
NF-kB Levels	Placebo	0.203
	<i>Rhodiola Rosea</i>	*0.005
TNF- α Levels	Placebo	*0.009
	<i>Rhodiola Rosea</i>	*0.002

* There was a significant difference ($p < 0.05$)

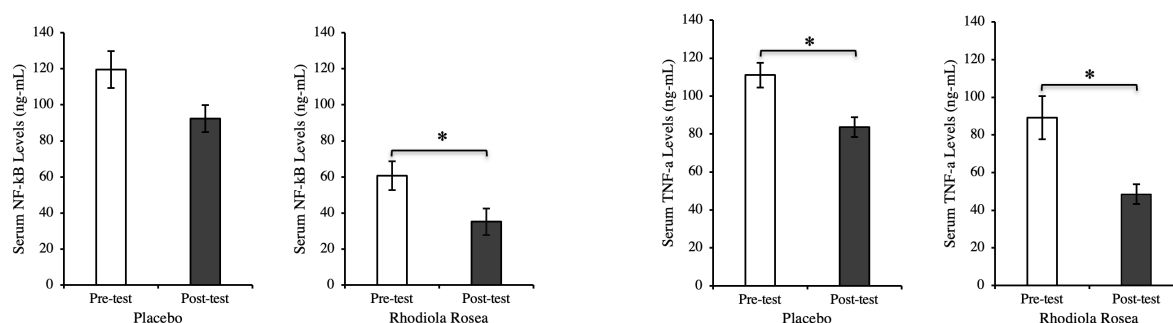


Fig. 1. Analysis of NF-kB and TNF- α levels between pre-test and post-test

Information: Groups given the *Rhodiola rosea* during EIMD can significantly decrease the levels of NF-kB (* $p < 0.05$) more than the placebo group. Further, the TNF- α was reported to have a significant reduction in both groups (* $p < 0.05$).

The data were presented in Mean $\pm$ Std Error

Discussions

This research measured if *Rhodiola rosea* affected the NF-kB and TNF- α levels after high-intensity training. We observed no significant difference in the NF-kB serum in the placebo group. However, a significant decrease was found in the TNF- α serum for the placebo and *Rhodiola rosea* groups. These findings confirmed earlier studies reporting the positive effect of *Rhodiola rosea* in reducing inflammation.

The high-intensity training can increase physiological responses, such as muscle damage and delayed muscle pain (Hung et al., 2021). The explosive movement during training lead to the high mechanical pressure and produces bone extracellular matrix fragments. These fragments are typically known as receptors expressed by inborn immune cells (Nanavati et al., 2022). Activating cells mediated by this process stimulates the activation of NF-kB (Jameson et al., 2021). Scholars argued that NF-kB plays an important role in regulating inflammatory responses, especially in the secretion of pro-inflammatory cytokines, like TNF- α (Nanavati et al., 2022).

Some muscle damage cases are caused by sports. When this happens, the histological study shows that neutrophil enters the muscle and accumulates in the area affected by the damage 1 to 24 hours after their participants do sports (Paulsen et al., 2010). In addition, the muscle damage is marked by the muscle ultrastructural disturbance that releases inflammatory cytokines by macrophages (Nanavati et al., 2022). Neutrophil and pro-inflammatory cytokines interact with each other in order to regulate the response of pro-inflammation when muscle damage occurs (Hody et al., 2019). On the other hand, when the pro-inflammatory cytokines increase, the macrophage also releases anti-inflammatory cytokines that allow muscles to recover and regenerate (Nonnenmacher & Hiller, 2018).

The present study believes that NF-kB is a therapeutic goal of *Rhodiola rosea* in inflammation (Jia et al., 2023). *Rhodiola rosea* is a plant that grows on the plateau. It is beneficial in pharmacological activities, serving as anti-cancer, anti-oxidant, and anti-inflammation (Xue et al., 2019). It has NF-kB, which is important in regulating and expressing TNF- α , which causes muscle pain. This study's findings are supported by previous research reporting salidroside as a bioactive component in *Rhodiola rosea*. Such components can decrease the degeneration of cartilage through the NF-kB pathway in osteoporotic mice (Gao et

al., 2020). Other studies have revealed that Rhodiola rosea is capable of weakening acute lung injury by inhibiting the NF- κ B pathways.

Another investigation points out that anti-inflammation affects Rhodiola rosea by potentially reducing the pro-inflammatory cytokines, such as TNF- α , IL-1 β , and IL-6 (Lee et al., 2013). Meanwhile, the present research found that TNF- α significantly fall in both the placebo and Rhodiola rosea groups. This finding might be triggered by the training program that we had in this research, which was not as heavy as the weight training conducted in Lee et al.'s study. Hence, since 48 hours after the training, the inflammation rate has decreased in both groups. Recent studies indicate that giving Omega 3 is effective in decreasing the TNF- α level and muscle pain after weight training (Ayubi et al., 2022).

In short, the laboratory examination conducted in this research showed that Rhodiola rosea with 600 mg/day potentially decreases the NF- κ B serum level. However, this research is limited in some ways. For instance, it does not investigate other inflammatory biomarkers, such as IL-10 and IL-1 β . In addition, it does not examine muscle damage biomarkers, like creatine kinase. Therefore, future research can assess the effect of Rhodiola rosea on these two biomarkers.

Conclusions

This research concludes that the provision of Rhodiola rosea with 500 mg/day has the potential to decrease NF- κ B levels. In addition, it reduces the TNF- α level in both the placebo and Rhodiola rosea groups. Future research can be directed to examine whether Rhodiola rosea also affect other inflammatory biomarkers, such as IL-10 and IL-1 β , and muscle damage biomarkers, like creatine kinase.

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Conflicts of Interest

The authors declare no conflict of interest.

References

- Hung, B.-L., Sun, C.-Y., Chang, N.-J., & Chang, W.-D. (2021). Effects of Different Kinesio-Taping Applications for Delayed Onset Muscle Soreness after High-Intensity Interval Training Exercise: A Randomized Controlled Trial. *Evidence-Based Complementary and Alternative Medicine*, 2021, 1-10. <https://doi.org/10.1155/2021/6676967>
- Amalraj, A., Divya, C., & Gopi, S. (2020). The Effects of Bioavailable Curcumin (Cureit) on Delayed Onset Muscle Soreness Induced By Eccentric Continuous Exercise: A Randomized, Placebo-Controlled, Double-Blind Clinical Study. *Journal of Medicinal Food*, 23(5), 545-553. <https://doi.org/10.1089/jmf.2019.4533>
- Ayubi, N., Purwanto, B., Rejeki, P. S., Kusnanik, N. W., Herawati, L., Komaini, A., Mutohir, T. C., Nurhasan, N., Al Ardha, M. A., & Firmansyah, A. (2022). Effect of acute omega 3 supplementation reduces serum tumor necrosis factor-alpha (TNF- α) levels, pain intensity, and maintains muscle strength after high-intensity weight training. *Retos*, 46, 677-682. <https://doi.org/10.47197/retos.v46.93720>
- Ayubi, N. (2022). Acute effects of n-3 polyunsaturated fatty acids (PUFAs) reducing tumor necrosis factor-alpha (TNF- α) levels and not lowering melondialdehyde (MDA) levels after anaerobic exercise. *Journal of Biological Regulators and Homeostatic Agents*, 36(1). <https://doi.org/10.23812/21-468-A>
- Zinatizadeh, M. R., Schock, B., Chalbatani, G. M., Zarandi, P. K., Jalali, S. A., & Miri, S. R. (2021). The Nuclear Factor Kappa B (NF- κ B) signaling in cancer development and immune diseases. *Genes & Diseases*, 8(3), 287-297. <https://doi.org/10.1016/j.gendis.2020.06.005>
- Park, M., & Hong, J. (2016). Roles of NF- κ B in Cancer and Inflammatory Diseases and Their Therapeutic Approaches. *Cells*, 5(2), 15. <https://doi.org/10.3390/cells5020015>
- Ezike, T. C., Okpala, U. S., Onoja, U. L., Nwike, C. P., Ezeako, E. C., Okpara, O. J., Okoroafor, C. C., Eze, S. C., Kalu, O. L., Odoh, E. C., Nwadike, U. G., Ogbodo, J. O., Umeh, B. U., Ossai, E. C., & Nwanguma, B. C. (2023). Advances in drug delivery systems, challenges and future directions. *Heliyon*, 9(6), e17488. <https://doi.org/10.1016/j.heliyon.2023.e17488>
- Mahesh, G., Anil Kumar, K., & Reddanna, P. (2021). Overview on the Discovery and Development of Anti-Inflammatory Drugs: Should the Focus Be on Synthesis or Degradation of PGE2? *Journal of Inflammation Research*, Volume 14, 253-263. <https://doi.org/10.2147/JIR.S278514>
- Tsagareli, M. G., Tsiklauri, N., Nozadze, I., & Gurtskaia, G. (2012). Tolerance effects of non-steroidal anti-inflammatory drugs microinjected into central amygdala, periaqueductal grey, and nucleus raphe: Possible cellular mechanism. *Neural regeneration research*, 7(13), 1029-1039. <https://doi.org/10.3969/j.issn.1673-5374.2012.13.010>
- Ivanova Stojcheva, E., & Quintela, J. C. (2022). The Effectiveness of Rhodiola rosea L. Preparations in Alleviating Various Aspects of Life-Stress Symptoms and Stress-Induced Conditions—Encouraging Clinical Evidence. *Molecules*, 27(12), 3902. <https://doi.org/10.3390/molecules27123902>
- Li, Y., Pham, V., Bui, M., Song, L., Wu, C., Walia, A., Uchio, E., Smith-Liu, F., & Zi, X. (2017). Rhodiola rosea L.: An Herb with Anti-Stress, Anti-Aging, and Immunostimulating Properties for Cancer Chemoprevention. *Current Pharmacology Reports*, 3(6), 384-395. <https://doi.org/10.1007/s40495-017-0106-1>
- Bernatoniene, J., Jakstas, V., & Kopustinskiene, D. M. (2023). Phenolic Compounds of Rhodiola rosea L. as the Potential Alternative Therapy in the Treatment of Chronic Diseases. *International Journal of Molecular Sciences*, 24(15), 12293. <https://doi.org/10.3390/ijms241512293>
- Nanavati, K., Rutherford-Markwick, K., Lee, S. J., Bishop, N. C., & Ali, A. (2022). Effect of curcumin supplementation on exercise-induced muscle damage: A narrative review.

- European Journal of Nutrition*, 61(8), 3835-3855.
https://doi.org/10.1007/s00394-022-02943-7
- Jameson, T. S. O., Pavis, G. F., Dirks, M. L., Lee, B. P., Abdelrahman, D. R., Murton, A. J., Porter, C., Alamdari, N., Mikus, C. R., Wall, B. T., & Stephens, F. B. (2021). Reducing NF- κ B Signaling Nutritionally is Associated with Expedited Recovery of Skeletal Muscle Function After Damage. *The Journal of Clinical Endocrinology & Metabolism*, 106(7), 2057-2076.
https://doi.org/10.1210/clinem/dgab106
- Paulsen, G., Cramer, R., Benestad, H. B., Fjeld, J. G., Mørkrid, L., Hallén, J., & Raastad, T. (2010). Time Course of Leukocyte Accumulation in Human Muscle after Eccentric Exercise. *Medicine & Science in Sports & Exercise*, 42(1), 75-85.
https://doi.org/10.1249/MSS.0b013e3181ac7adb
- Hody, S., Croisier, J.-L., Bury, T., Rogister, B., & Leprince, P. (2019). Eccentric Muscle Contractions: Risks and Benefits. *Frontiers in Physiology*, 10, 536.
https://doi.org/10.3389/fphys.2019.00536
- Nonnenmacher, Y., & Hiller, K. (2018). Biochemistry of proinflammatory macrophage activation. *Cellular and Molecular Life Sciences*, 75(12), 2093-2109.
https://doi.org/10.1007/s00018-018-2784-1
- Jia, X., Zhang, K., Feng, S., Li, Y., Yao, D., Liu, Q., Liu, D., Li, X., Huang, J., Wang, H., & Wang, J. (2023). Total glycosides of *Rhodiola rosea* L. attenuate LPS-induced acute lung injury by inhibiting TLR4/NF- κ B pathway. *Biomedicine & Pharmacotherapy*, 158, 114186.
https://doi.org/10.1016/j.biopha.2022.114186
- Xue, H., Li, P., Luo, Y., Wu, C., Liu, Y., Qin, X., Huang, X., & Sun, C. (2019). Salidroside stimulates the Sirt1/PGC-1 α axis and ameliorates diabetic nephropathy in mice. *Phytomedicine*, 54, 240-247.
https://doi.org/10.1016/j.phymed.2018.10.031
- Gao, H., Peng, L., Li, C., Ji, Q., & Li, P. (2020). Salidroside Alleviates Cartilage Degeneration Through NF- κ B Pathway in Osteoarthritis Rats. *Drug Design, Development and Therapy*, Volume 14, 1445-1454.
https://doi.org/10.2147/DDDT.S242862
- Lee, Y., Jung, J.-C., Jang, S., Kim, J., Ali, Z., Khan, I. A., & Oh, S. (2013). Anti-Inflammatory and Neuroprotective Effects of Constituents Isolated from *Rhodiola rosea*. *Evidence-Based Complementary and Alternative Medicine*, 2013, 1-9. https://doi.org/10.1155/2013/514049

Вплив родіоли рожевої на показники рівнів ядерного фактора каппа-В та фактора некрозу пухлини альфа після проведення високоінтенсивних тренувань

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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., 1 рис., 21 джерело.

Мета дослідження. Метою цього дослідження було проаналізувати вплив родіоли рожевої на показники рівнів ядерного фактора каппа В (NF- κ B) та фактора некрозу пухлини альфа (TNF- α) після проведення високоінтенсивних тренувань.

Матеріали та методи. Дослідження проводилося за допомогою експериментального методу із застосуванням перед-тестового та післятестового групового планування. В якості учасників дослідження було залучено 20 здорових осіб чоловічої статі. Їхній середній вік становив 19 років, і на даний момент вони є студентами закладів вищої освіти. Учасників було цілеспрямовано відібрано та розподілено на дві групи. В одній групі призначали плацебо (вік = $19,60 \pm 0,69$), в той час як інша була віднесена до медикаментозної групи, яка отримувала родіолу рожеву в дозуванні 500 мг (вік = $19,30 \pm 0,82$). Процес дослідження розпочався зі збору даних суб'єктів дослідницького експерименту в перший день його проведення. Після цього учасникам було запропоновано провести розминку перед виконанням високоінтенсивного фізичного тренування, яке включало в себе такі фізичні вправи, як ходьба з випадами, нахили зі штангою на плечах, або як ще називають – вправа “Good Morning” (тренування з обтяженням) та розгинання ніг. Тренування проводилося протягом 4 підходів з перервою на відновлення тривалістю 1 хвилини між підходами. Інтенсивність тренування контролювали за допомогою датчика частоти серцевих скорочень Polar H9. На другий день (через 24 години після тренування) у всіх досліджуваних осіб було відібрано зразки крові. Ці результати розглядалися як дані передтестового моніторингу для розрахунку показників рівнів NF- κ B та TNF- α . На наступному етапі дослідження учасники отримували плацебо та родіолу рожеву відповідно до попередньо визначених груп. На третій день (через 48 годин після тренування) в учасників дослідження повторно було відібрано зразки крові. Збір крові проводився вже після завершення тренування з метою визначення післятестових даних. Наступна процедура включала аналіз зразків крові в лабораторії із застосуванням імунологічного методу дослідження ELISA. Крім того, для проведення статистичного аналізу цього дослідження використовувалося програмне забезпечення SPSS.

Результати. Результати дослідження показали, що в групі осіб, які приймали плацебо, не виявлено суттєвої різниці в показниках рівнів NF-kB у сироватці крові, тоді як у учасників, які отримували родіолу рожеву, спостерігалось помітне зниження рівня NF-kB у сироватці крові. До того ж, в обох групах відзначалось істотне зниження рівня TNF-α у сироватці крові.

Висновки. Підсумовуючи, можна стверджувати, що прийом родіоли рожевої у дозі 500 мг/добу потенційно сприяє зниженню рівня NF-kB. Водночас, в обох групах спостерігалось зниження рівня TNF-α у сироватці крові. Отже, рекомендується провести подальші дослідження щодо вивчення впливу родіоли рожевої на інші маркери запалення, включаючи інтерлейкін-10 (IL-10) та інтерлейкін-1β (IL-1β), а також біомаркери пошкодження м'язів, такі як креатинкіназа.

Ключові слова: родіола рожева, пошкодження м'язів внаслідок фізичних навантажень, запалення, здоров'я.

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The Thai Folk Game “Jik Sen” has Become a Recreational Sport for Older People in Senior Citizen Schools

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Abstract

Objectives. The purposes of this study were to: 1) develop an exercise program incorporating the Thai recreational sport “Jik Sen” for older people in senior citizen schools; 2) investigate the effects of the exercise program incorporating the Thai recreational sport “Jik Sen” on the physical fitness of older people in senior citizen schools; and 3) assess the satisfaction level of older people with the exercise program incorporating the Thai recreational sport “Jik Sen”.

Materials and methods. This was a two-group experimental study including the experimental group of 17 people (65.53 ± 3.43 years) and the control group of 17 people (65.76 ± 3.60 years). The participants in this study were healthy individuals aged 60 years and above, who were actively engaged in the elderly school program. They were selected using a purposive sampling method and subsequently assigned them to the experimental and control groups using a matching method based on BMI. The research tools consisted of the exercise program, which incorporated the Thai recreational sport “Jik Sen” developed by the research team, and the Senior Fitness Test (SFT). For a period of 8 weeks, the experimental group involved in an exercise regimen comprising 60 minutes of daily training in the Thai recreational sport “Jik Sen”, with a frequency of 3 days per week. The control group was instructed to maintain their normal daily routine and did not participate in any physical activities or exercise programs during the experiment. The data were analyzed using mean, standard deviation, percentage, and t-test.

Results. 1) The exercise program incorporating the Thai recreational sport “Jik Sen” for older people in senior citizen schools can be appropriately used to promote exercise and sports in elderly schools in Thailand. The IOC value was 0.97. 2) A significant difference was observed in the mean scores of the 8-foot up-and-go test between the pre-experimental (mean = 7.94, SD = 1.34) and post-experimental (after 8 weeks) (mean = 6.70, SD = 0.79) periods for the experimental group at the level of 0.05. The mean scores of the 8-foot up-and-go test between the control group (mean = 7.84, SD = 1.16) and the experimental group (mean = 6.70, SD = 0.79) were also found to be significantly different at the level of 0.05. 3) The experimental group expressed high levels of satisfaction with the exercise program involving the Thai recreational sport “Jik Sen” for older people in senior citizen schools, with a mean score of 4.62 ± 0.51 points.

Conclusions. The exercise program incorporating the Thai recreational sport “Jik Sen” can effectively enhance the dynamic balance of older individuals in senior citizen schools. Furthermore, it has been shown to facilitate social interaction, improve cognitive abilities including thinking and planning skills, and promote enjoyment.

Keywords: elderly schools, older people, physical fitness, recreational sport, Thai folk game.

Introduction

Over the past 20 years, the number of older people in Thailand has steadily increased as in many countries around

the world (Department of Economic and Social Affairs, 2023), and it is still an increasing trend at the present (Department of Older Persons, 2023a; Teerawichitchainan et al., 2020; Thaithatkul et al., 2022). In addition to the issue of the continuously increasing number of older people, it has also been found that Thai older people tend to live longer (Department of Older Persons, 2023a). Although living a longer life of Thai older people is a good thing,

not all Thai older people have good health and are able to rely on themselves and cope with the rising costs of living in today's society, especially the cost of medical care. As a result, this population group often has health problems caused by deterioration of the body, finally, leading illnesses and disabilities. Consequently, the demand for long-term care is increasing (Ladavanich & Chalongsamdee, 2016). The problems of shortage of caregivers for older people and abandonment of older people must be concerned and urgently solved by Thai government agencies in order to prevent the problems which may happen in the near future.

Thailand has taken proactive steps and approaches to address the problems caused by the continued rise in the number of Thai older people (Department of Elderly Affairs, 2023), including the establishment of elderly schools under the concept that “Older people have value and potential that should be encouraged and supported to participate in making contributions to society and lifelong learning should be promoted for older people” (Department of Older Persons, 2017). This is to encourage older people to have self-care skills, earn income, and be able to live their lives on their own by relying on other people as little as possible (Charoenwisal & Dhammasaccakarn, 2022; Kulachada & Mitchell, 2019; Ratana-Ubol, 2021). A survey in 2023 revealed that there were 2,390 elderly schools across all regions of Thailand, and the number of elderly students increased to 169,901 people (Department of Older Persons, 2023b). The activities in the elderly school curriculum mainly include providing knowledge about self-care, developing appropriate career skills and promoting various types of recreational activities in order to enhance and develop the quality of life of older people (Aroonsrimorakot et al., 2022; Department of Older Persons, 2017).

Recreational activities offer numerous benefits for the elderly, contributing to their physical, mental, and social well-being. Engaging in leisure activities has been associated with improved physical health outcomes such as enhanced mobility, balance, and cardiovascular health (Cohen-Mansfield et al., 2019). Furthermore, participation in recreational pursuits promotes social interaction, reducing the risk of social isolation and loneliness commonly experienced by older adults (Wang et al., 2016). In the context of elderly schools in Thailand, exercise and sports are considered important and necessary recreational activities. All schools often use such activities to promote physical fitness and health of older people. However, from the review of previous research, it was found that the exercise and sports activities of older people in elderly schools are still quite limited and there are relatively few studies. Examples of popular activities include aerobic dance, ballroom dancing, Petanque, Woodball, etc. (Kaewsuphan et al., 2023). There are also limitations on the locations of elderly schools in Thailand. The meeting room of the Sub-district Administrative Organization and the temple's sermon hall are used as the locations for some elderly schools. Also, school buildings may be built as classrooms of elderly schools. However, most classrooms are single-story buildings, which are not very large. Therefore, if sports that can be played indoors are developed for older people, it does not take up much of the playing space and is safe for older people. It should also help motivate and stimulate adequate physical activity among older people in elderly schools in Thailand.

Folk play, a traditional form of cultural expression, holds educational, social, and entertainment values that are passed

down through generations (Asante & Sam, 2022; Choi & Park, 2022). These play games are integral to preserving intangible cultural heritage and promoting community cohesion (Ramani, 2022; Thu, 2022). However, the modernization of aesthetics and the advent of digital entertainment pose challenges to the sustainability of folk plays, leading to a decline in their popularity and transmission to younger generations. Thai folk games are considered recreational activities that create fun for the participants and spectators that help promote exercise and social skills (Hnawinchot et al., 2019; Sangiamvibool & Chommanee, 2020; Tangsirirup & Butsatorn, 2020; Thonglong & Bussamongkhon, 2022). They have been continuously played and passed down from generation to generation since ancient times. The sports developed from Thai folk games that are well known internationally include Takraw, Thai boxing, and Krabi-Krabong, etc. (Komaratat et al., 1984).

“Jik Sen” is a gambling folk game that is very popular in the northeastern region of Thailand (Tongterm, 2013). The rules, regulations, and methods of playing are similar to those of Petanque. That is, when playing Petanque, players must throw the petanque ball as close to the Petanque target ball as possible in order to win the game. As for Jik Sen, players must try to throw their playing equipment as close to the mid-field line as possible. The player who can throw closest to the mid-field line is the winner of the game. In the past, many types of equipment were used for this game, such as elastic bands, rubber puppets, baht coins, and soda caps with flat edges. These are items that children can find easily, and are inexpensively, or leftover materials from their own households. A previous study revealed that the research team developed “Jik Sen” a recreational sport for youth, and it was found that “Jik Sen” could create fun for both players and spectators and help develop the physical fitness of youth with high safety (Tongterm et al., 2023).

Based on the aforementioned important information in terms of the increasing number of Thai elderly people, the sports and recreational activities suitable for older people in elderly schools that are still quite limited and the situation of Thai folk games that have received less attention in today's society, the research team was interested in 1) developing the exercise program with the Thai recreational sport “Jik Sen” for older people in elderly schools, 2) investigating the effects of the exercise program with the Thai recreational sport “Jik Sen” on the physical fitness of older people in elderly schools and 3) assessing the satisfaction of older people with the exercise program with the Thai recreational sport “Jik Sen” developed by the research team. In addition to obtaining an alternative form of exercise for older people in elderly schools, the research team also expects that the results of this research will help promote the conservation of Thai folk games so that they do not disappear from Thailand and encourage the new generation of Thai youth to become interested in Thai folk games.

Materials and Methods

Study Design

This was two-group experimental research: the control group (CG) and the experimental group (EG). The experimental plan is presented below.

CG (n=20) M O₁ X₁ O₂EG (n=20) M O₃ O₄

M – refers to the selection of samples to the experimental group and the control group using the matching method based on BMI.

X₁ – refers to the participation in the exercise program with the Thai recreational sport “Jik Sen” developed by the research team.

O₁, O₃ – refers to the physical fitness test before the experiment.

O₂, O₄ – refers to the physical fitness test after the 8th week of the experiment.

Study Participants

The population included 127 older people at Duan Yai Rom Pho Thong School for the Elderly in 2022 (Duan Yai Administrative Organization, 2022).

The sample size was calculated using the G*Power program version 3.1.9.7 (Faul et al., 2009) based on the physical fitness test results of body flexibility before and after the experiment of a previous study by Petchalalai & Udompanich (2019). The effect size was 1.47. The significance level was set at 0.05 and the power of the test was 95% ($1-\beta=0.95$). As a result, the appropriate sample size was 11 people per group. However, to prevent the drop-out during data collection, 80% of the calculated sample size was added in each group (9 people per group). Therefore, the total sample size was 40 people: 20 people in the experimental group and 20 people in the control group. The inclusion criteria and the exclusion criteria were as follows.

Inclusion criteria:

- 1) Students studying at Duan Yai Rom Pho Thong School for the Elderly in 2022 aged 60 years and over.
- 2) Not having medical indication prohibiting exercise.
- 3) Not taking medicines or dietary supplements that affect physical fitness.

- 4) Willing to participate in the research.

Exclusion criteria:

- 1) Exercising/playing sports regularly, starting from 3 days/week (30 minutes per day) and continuously for at least 3 months before participating in the research.
- 2) Having participated in a trial exercise program in the 3 months before participating in the research.

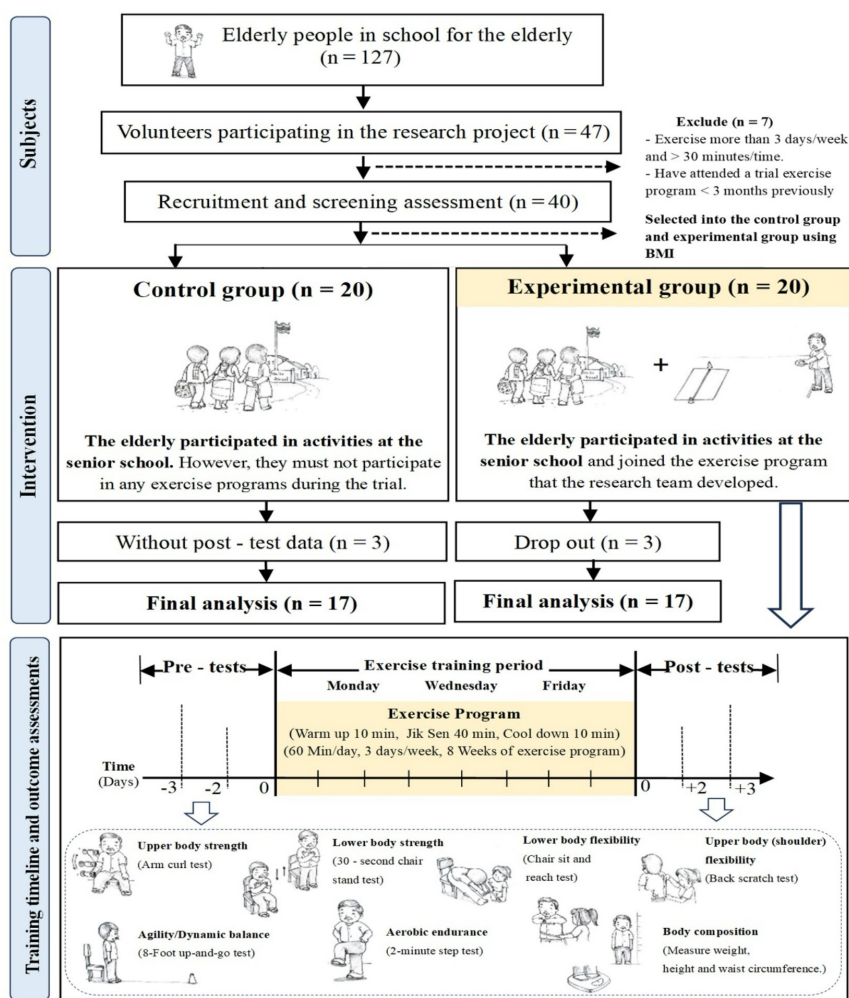


Fig. 1. Outline of training and testing schedule

3) Having heart disease complications or diseases related to the respiratory system.

4) Having accidents, complications, and bone and joint diseases while participating in the research.

5) Unable to participate in the research until it is completed or wishing to leave the research.

Forty elderly volunteers participating in this research were randomly assigned into 2 groups: the experimental group of 20 people and the control group of 20 people based on BMI using a simple random sampling method (Table 1).

During the research process, 3 participants in the experimental group dropped out of the experiment, and 3 participants in the control group could not be followed up to collect post-test data. Therefore, this study used a total of 34 samples for data analysis: the experimental group of 17 people and the control group of 17 people, as shown in Fig. 1.

Table 1. Method of dividing the participants into the experimental group and the control group based on BMI (n = 40)

Female (n = 32)		Male (n = 8)	
Group 1 (n = 16) Experimental group	Group 2 (n = 16) Control group	Group 1 (n = 4) Experimental group	Group 2 (n = 4) Control group
(The highest) The 1 st	The 2 nd	(The highest) The 1 st	The 2 nd
The 4 th	The 3 rd	The 4 th	The 3 rd
The ...	The ...	The 5 th	The 6 th
(The lowest) the 32 nd	The 31 st	(The lowest) the 8 th	The 7 th

Research Tools

1) The exercise program with the Thai recreational sport “Jik Sen” for older people in elderly schools: It was developed from the recreational sport “Jik Sen” for youth proposed by Tongterm et al. (2023). This exercise program consisted of 3 steps: a 10-minute warm-up step, a 40-minute Jik Sen playing step and a 10-minutes cool down step (Table 2). The face validity was evaluated by 5 experts in sports science and physical education. It was found that the exercise program could be appropriately and safely used for older people in elderly schools. Moreover, the content validity was evaluated using the index of item objective congruence (IOC), and the IOC was 0.97. The experimental group did exercise training for a period of 8 weeks, 3 days per week (Monday, Wednesday, and Friday), 60 minutes a day. Every day of the experiment, the participants in the experimental group were divided into 4 teams. The experiments were conducted during the same time period, 4:00-5:00 p.m., while the control group was instructed to carry out their normal daily routine. They must

not participate in any other physical activity experiments during this research study.

2) Senior Fitness Test (SFT) (Rikli & Jones, 1999a; 1999b): It was employed to assess 7 aspects of physical fitness including: 1) lower body strength assessed by 30 – second chair stand, 2) upper body strength assessed by arm curl test, 3) cardiorespiratory endurance assessed by 2-minute step test, 4) upper body flexibility assessed by back scratch test, 5) lower body flexibility assessed by chair sit-and-reach test, 6) agility/dynamic balance assessed by the 8-foot up-and-go test and 7) body composition assessed by Body Mass Index (BMI) and waist circumference (Fig. 1).

3) The satisfaction assessment form for the exercise program with the Thai recreational sport “Jik Sen”: The responses are on the 5-point Likert scale (Shonkoff et al., 2016) as follows: (a) 5 = the highest level of satisfaction; (b) 4 = a high level of satisfaction; (c) 3 = a moderate level of satisfaction; (d) 2 = a low level of satisfaction; and (e) 1 = the lowest level of satisfaction.

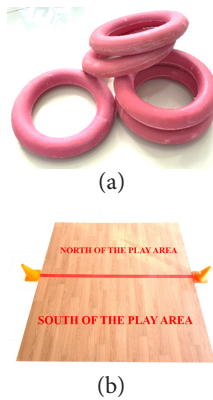
Table 2. The exercise program with the Thai recreational sport “Jik Sen”

No	Practice	Method of action
Warm Up (10 minutes)		
The warm-up period of the experimental group consisted of 6 poses in the following order:		
1		– Sit on a chair with a straight back and stretch the arms out in a palm-down position. – Clench and unclench the fingers slowly, repeating 10 times. – Turn the hands over and clench and unclench the fingers slowly, repeating 10 times. – Stretch the arms out in a palm-down position and flick the wrists continuously for 30 seconds.
Fig. 2. Pose 1: Fingers Clenched		
2		– Sit on a chair with a straight back (slightly in front of the chair). – Stretch the right knee forward as far as possible and hold for 5 seconds and slowly return to the starting position. – Repeat the same posture, 10 times on each side. – Lift the right leg alternating with the left leg continuously as fast as possible for 30 seconds.
Fig. 3. Pose 2: Knee Stretching		
3		– Stand up straight behind a chair and use the hands to hold onto the edge of the chair (to prevent falling). – Slowly lower down by bending the knees into a squat position according to the individual's ability and hold in the squat position for 5 seconds. – Return to the starting position. – Repeat the same posture 10 times.
Fig. 4. Pose 3: Squat		

Table 2 (continued)

No	Practice	Method of action
4		– Stand up straight behind a chair and use the hands to hold the edge of the chair. – Raise both toes slowly and hold for 5 seconds. – Return to the starting position. – Repeat the same posture 10 times.
Fig. 5. Pose 4: Standing on Tiptoes		
5		– Stand upright on the side of a chair with one hand on the chair. – Slowly swing the leg back and forth, keeping the knee straight as far as possible. – Contract the buttock and leg muscles and hold for about 5 seconds. – Slowly pull the leg back, and slowly swing the leg forward as far as possible. – Contract the leg and hold for about 5 seconds, then return to the starting position. – Repeat the same posture by alternating right-left leg, 5 times on each side. – Swing you're the leg alternating back and forth as quickly as possible (height depends on the ability of each volunteer). – Alternate the right-left leg for 30 seconds on each side.
Fig. 6. Pose 5: Leg Swings		
6		– Stand up straight with one hand on a chair. – Raise the right knee forward and try to bring the knee as close to the chest as possible, hold for 5 seconds and return to starting position. – Alternate the right-left leg, 5 times on each side. – Stomp on the feet (in place) and raise the knee up for 30 seconds.
Fig. 7. Pose 6: Standing with Legs Raised		

Table 2 (continued)

No	Practice	Method of action
Exercise Time (40 minutes)		
	 Fig. 8. The experimental group participating in the exercise program with Thai recreational sport “Jik Sen”	The recreational sport “Jik Sen” was developed from Thai folk game, called “Jik Sen” that is popularly played in the northeastern region of Thailand. The rules, regulations, and playing methods can be briefly described as follows: (1) Players: “Jik Sen” is a team sport, consisting of 5 players/team. (2) Play area: The field is made of rubber tiles with 2 meters wide, 2 meters long, and 1.5 millimeters thick. The mid-field line is 5 centimeters wide (red) with 2 short cones (Figure 9(b)). (3) Materials: Rubber rings with a round shape, 16 centimeters in diameter, 3 centimeters of thickness and 200 grams/ring (Figure 9(a)). Fifteen rubber rings will be given to each team/game. That is, 3 rubber rings will be given to each player/game. One player can throw 3 rubber rings per game. Each player cannot throw for the other. The players from both teams will receive different colored rubber rings, for example Team A will get red rubber rings and Team B will get blue rubber rings. (4) Competition format: Two teams per round will be competed. In this research, a mixed team playing style was used. (5) Duration: The duration of play is not limited. Whichever team can accumulate 100 points first is the winner. (6) Scoring: Scores will be counted one game at a time. In each game, a total of 30 rings will be used (both teams’ rubber rings). That is, when all 30 rings are played, it is called 1 game, and the referee will count the scores for one round. When the game is finished, the play area for scoring will be divided into 2 sides: the north of the play area and the south of the play area. One rubber ring in the field boundary will be counted as 1 point. The scoring methods are as follows. (6.1) Scoring is made separately based on the 2 play areas, namely the north of the play area and the south of the play area (Figure 9(b)). (6.2) Scoring is made for each play area at a time (the north/the south of the play area). Whichever team’s rubber rings are closest to the mid-field line is the winner on that side and will receive points equal to all the rubber rings within the boundary of that side’s field (all rings that fall within the boundary of that side’s field are counted). If a rubber ring is found close to the edge of the field with any point of the rubber ring overlapping the field line, it is considered that the rubber ring is still on the field and scored. As for the rubber ring that has no point touching the field, it will be counted as a negative score. That is, scoring on both the north and the south of the play area must be done first. After that, the scores for the rubber rings outside the field area will be subtracted. One rubber ring outside the boundary of the field is -1 point. So, in some games, the team may get negative scores because there are no scores from the play area and the points are deducted from throwing the rubber ring outside the play area. This is at the discretion of the referees, and the referees’ decision shall be considered final. (7) Lose – win: Whichever team can accumulate 100 points first is the winner. But in the case of the last game that both teams get more than 100 points, the team with the highest score is the winner. The competition will continue until there is the winning team. (8) Breaks between games: “Jik Sen” is a continuously playing game. However, players can sit and rest or stand when it is not their playing order. The order of play depends on the planning of each team. (9) Substitution of players: Players on each team can only make substitutions at the end of each game, not during the game, and each team has the right to make an unlimited number of substitutions. (10) Foul: There is one type of foul, which is the player steps on the line while throwing the rubber ring (the point at which the throw is determined). If one team’s players commit 5 fouls, the other team will receive an additional 1 point, and the action will be taken every time such fouls occur. (11) Referees: There are 3 referees, consisting of 1 referee, 1 lineman, and 1 assistant scorer. (12) Playing methods: The methods of playing the recreational sport “Jik Sen” are similar to those of Petanque. To play Petanque, players must try to throw the ball as close to the target ball (jack) as possible. The team that can throw the ball closer to the target ball will win each round of the game. But for “Jik Sen”, players must try to throw the rubber ring as close to the mid-field line as possible (red line). Players can throw their rubber rings to cause the rubber rings of either their own team or those of the opponent on the field to bounce off (Figure 8). Those interested in the recreational sport “Jik Sen” for the elderly can see an example of how to play it at https://www.youtube.com/watch?v=uQzBeRPVvOQ&t=99s.
	 Fig. 9. (a) Materials for playing “Jik Sen”, (b) The boundary of the play area for scoring	

Cool Down (10 minutes)

During the cool down, the participants in the experimental group performed a total of 6 poses, including Pose 1: Standing with Legs Raised; Pose 2: Leg Swings; Pose 3: Standing on Tiptoes; Pose 4: Squat; Pose 5: Knee Stretching; and Pose 6: Fingers Clenched. That is, they performed the same poses as during the warm-up period but with the change of the sequence of poses, starting from Pose 6 to Pose 1.

Human Research Ethics

This study received approval from the Research Ethics Review Committee of Sisaket Rajabhat University on December 1, 2022 (HE651013). Each volunteer provided informed consent.

Statistical Analysis

The participants characteristics were analyzed by mean, standard deviation, and percentage. The physical fitness data for all variables were tested for normal distribution before the experiment using the Shapiro-Wilk Test. The mean physical fitness test results between before and after the experiment were compared within the group using paired t-test. The means between the groups before the experiment and after the 8th week of the experiment were compared using independent t-test. The statistical significance was tested at the 0.05 level. The satisfaction assessment results of the experimental group with the exercise program (i.e., the recreational sport “Jik Sen”) were analyzed based on the following scores: 5 points = extremely satisfied, 4 points = very satisfied, 3 points = moderately satisfied, 2 points = slightly satisfied, and 1 point = not at all satisfied. The results of satisfaction levels on each aspect and overall satisfaction were summarized using mean and standard deviation (SD). The 5 levels of assessment criteria were defined with the following score ranges (Rezwan et al., 2022). A mean score of 1.00 to 1.50 indicates the lowest level of satisfaction. A mean score of 1.51 to 2.50 indicates a low level of satisfaction. A mean score of 2.51 to 3.50 indicates a moderate level of satisfaction. A mean score of 3.51 to 4.50 indicates a high level of satisfaction. A mean score of 4.51 to 5.00 indicates the highest level of satisfaction.

Results

This study involved 34 older people at Duan Yai Rom Pho Thong School for the Elderly, divided into 17 in the control group (4 males and 13 females, with an average age of 65.53 ± 3.43 years) and 17 in the experimental group (4 males and 13 females, with an average age of 65.76 ± 3.60 years).

The general information of the participants is presented in Table 3. Before the experiment, no significant differences were found in the mean scores of all physical fitness tests at the level of 0.05 in both the experimental group and the control group (Table 4).

Table 4. Mean scores in physical fitness in all 2 groups after 8-week training

Parameters	CG (n = 17)				EG (n = 17)			
	Pre-test	Post-test	t	P-value	Pre-test	Post-test	t	P-value
BMI (kg/m ²)	22.78 ± 2.28	23.14 ± 2.47	-2.45	0.03*	22.88 ± 1.85	22.80 ± 1.97	0.60	0.56
WC (inches)	32.15 ± 3.71	32.35 ± 3.94	-0.37	0.71	31.91 ± 4.07	31.82 ± 3.48	0.16	0.87
Chair stand (no. of stands)	15.82 ± 2.19	15.12 ± 2.15	1.62	0.12	15.24 ± 2.86	16.00 ± 2.78	-1.23	0.24
Arm curl (no. of reps)	18.29 ± 3.37	18.12 ± 2.34	0.26	0.80	18.06 ± 4.12	18.94 ± 2.70	-1.16	0.26
2-Min step (no. of steps)	83.59 ± 18.39	84.12 ± 17.95	-0.17	0.86	83.65 ± 19.87	86.94 ± 20.85	-1.55	0.14
Back scratch (inches +/-)	-2.79 ± 3.70	-2.82 ± 2.84	0.06	0.95	-2.76 ± 3.29	-2.44 ± 3.22	-0.47	0.64
Chair sit and reach (inches +/-)	3.24 ± 3.87	3.65 ± 3.84	-0.51	0.62	3.88 ± 4.09	5.18 ± 3.56	-2.09	0.05
8-Foot up-and-go (seconds)	8.09 ± 1.13	7.84 ± 1.16	1.03	0.32	7.94 ± 1.34	6.70 ± 0.79	5.20	0.01*†

Description: *Significant $p < 0.05$ (pre vs post), †Significant $p < 0.05$ (CG vs EG)

Table 3. Baseline characteristics of cardiovascular parameters in the CG and the EG (n=34)

Parameters	CG (n = 17)	EG (n = 17)
Age (y)	65.53 ± 3.43	65.76 ± 3.60
Weight (kg)	58.76 ± 5.77	59.06 ± 6.89
Height (cm)	160.71 ± 6.62	160.47 ± 6.30
BMI (kg/m ²)	22.78 ± 2.28	22.88 ± 1.85
Waist circumference (inches)	32.15 ± 3.71	31.91 ± 4.07
Resting heart rate (b/m)	78.24 ± 11.04	77.65 ± 9.01
SBP (mm/Hg)	137.00 ± 21.43	135.47 ± 13.15
DBP (mm/Hg)	79.12 ± 13.69	88.41 ± 19.27

Descriptions: CG: control group and EG: experimental group; BMI: body mass index; WC: Waist circumference; SBP: systolic blood pressure; DBP: diastolic blood pressure. Values are mean ± SD. No significant difference was found between the two groups for any variable

Table 4 shows the mean values of physical fitness before and after 8 weeks of training. It was found that the EG, the mean scores of the 8-foot up-and-go test between the pre-test and the post-test were significantly different at the level of 0.05. Also, after the 8th week of the experiment, the EG had better mean test results for the 8-foot up-and-go test than before the experiment (Table 4).

In particular, after 8 weeks of training, the comparison results of the physical fitness test between the CG and the EG revealed a significant difference in mean scores of the 8-foot up-and-go test at the level of 0.05 (Table 4 and Figure 10).

The EG expressed satisfaction with the exercise program incorporating the Thai recreational sport “Jik Sen” for older individuals in elderly schools, which was developed at the highest level by the research team (Table 5).

Discussion

The exercise program with the Thai recreational sport “Jik Sen” for older people in elderly schools was developed from the recreational sport “Jik Sen” for youth proposed by Tongterm et al. (2023). The results of the experiment showed that the appropriate playing distance for older people was a throwing distance of 4 meters. The exercise program consisted of 3 steps: a 10-minute warm-up step, a 40-minute Jik Sen playing step and a 10-minutes cool down step, 60 minutes in total (Table 2). The findings revealed that the exercise program with the Thai recreational sport “Jik Sen” can be

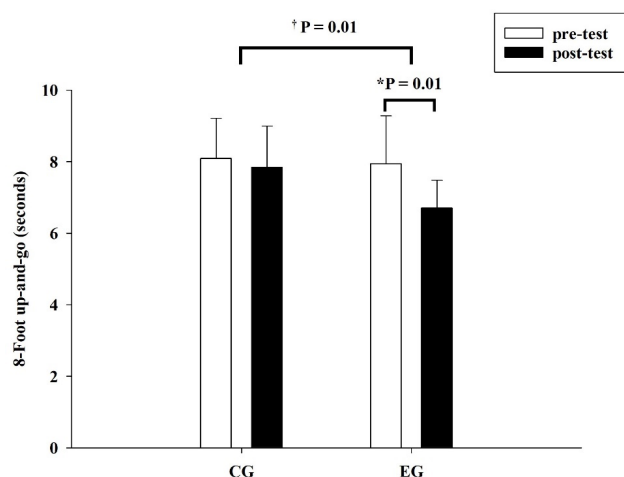


Fig. 10. Changes in 8-Foot up-and-go before and after 8-week of the training period. Values are present as mean $\pm$ SD. *Significant $p < 0.05$ (pre vs post), †Significant $p < 0.05$ (CG vs EG)

Table 5. The results of the assessment of the satisfaction of the older people in the EG on the exercise program with the Thai recreational sport “Jik Sen” for older people in elderly schools developed by the research team ($n = 17$)

Topics	Results	
	Mean $\pm$ SD	Satisfaction level
1. Equipment, field, rules and regulations.	4.52 $\pm$ 0.56	Highest
1.1. The equipment is appropriate.	4.53 $\pm$ 0.62	High
1.2. The field is appropriate.	4.53 $\pm$ 0.51	High
1.3. The rules are clear and appropriate.	4.41 $\pm$ 0.62	High
1.4. The criteria for wins and losses are clear and appropriate.	4.41 $\pm$ 0.62	High
1.5. The duration of the competition (per pair) is appropriate.	4.65 $\pm$ 0.49	Highest
1.6. The referees are adequate (3 people/field) and appropriate.	4.59 $\pm$ 0.51	Highest
2. Suitability for the elderly.	4.69 $\pm$ 0.53	Highest
2.1. The rules and regulations are easy to understand.	4.53 $\pm$ 0.72	Highest
2.2. It is safe to play.	4.71 $\pm$ 0.47	Highest
2.3. It is suitable for organizing competitions for the elderly.	4.82 $\pm$ 0.39	Highest
3. Value for the elderly.	4.65 $\pm$ 0.48	Highest
3.1. It is fun.	4.76 $\pm$ 0.44	Highest
3.2. It creates unity.	4.76 $\pm$ 0.44	Highest
3.3. It helps develop thinking and planning skills.	4.53 $\pm$ 0.51	Highest
3.4. It helps develop physical fitness.	4.53 $\pm$ 0.51	Highest
Overall	4.62 $\pm$ 0.51	Highest

appropriately used among older people in the elderly school. This may be because the recreational sport “Jik Sen” has light intensity that does not cause the older people to become fatigued from excessive playing. It was found that more than 90% of older people in the elderly school were able to participate in this activity very well. In addition, the recreational sport “Jik Sen” has rules, regulations, and methods of playing that are not complicated. Older people can easily understand how to play it. The playing materials (rubber rings) are also very safe. Older people can pick up and hold the rubber ring easily because it is circular in shape with a hole in the middle, similar to a donut. If the rubber ring falls out of the player’s hand or falls on the floor, it does not cause much danger or injury to the player’s body because it is relatively lightweight (200 grams) and very flexible. In addition, this exercise program was developed with the main objective of being used as an indoor recreational activity in order to avoid the extremely hot weather of Thailand. However, it can be played both indoors and outdoors with the same standards because the equipment and the competition field can be moved. As for the price of playing materials, rubber rings are cheap and can be easily purchased online. The last point that is considered a highlight of this exercise program is that it was developed from the Thai folk game “Jik Sen” which was very popular in the past. Therefore, older people feel familiar with it because they know and had experience playing it in the past.

Changes in test results of the 8-foot up-and-go test after the 8th week of the experiment was reflected that the agility and dynamic balance of the older people improved due to participation in the exercise program with the Thai recreational sport “Jik Sen”. Participating in this exercise program allows older people to move their bodies by getting up from and sitting on their chairs, walking to start playing the game (throwing rubber rings), walking to the play area to plan the game and analyze the results of each game. Walking back and sitting in their own chairs (throwing distance of 4 meters), squatting and swinging the arms to send force to the rubber ring while throwing, stretching the body while throwing the rubber ring to shorten the throwing distance cause the leg muscles to be used in continuous movement, resulting in more efficient motor unit and muscle contraction. Repeated these movements will cause motor recruitment to be used to increase muscle contraction and the working frequency of that motor unit, resulting in muscle contraction and strength (Adliah & Rini, 2023; Martini et al., 2022; Vittala & Setiawan, 2023). When older people have better muscle strength in the lower body, it can result in better balance while moving (Hemachithra & Booshaa, 2022). Many previous studies found that practicing a variety of different types of walking can help promote balance (Malasari et al., 2022; Rusminingsih, 2021; Shier et al., 2016) and reduce the risk of falls among the elderly (Rusminingsih et al., 2021). In addition, the warm up and cool down postures, including Squat, Standing on Tiptoes, Leg Swings and Standing with Legs Raised also help improve balance among older people. The findings also revealed that the physical fitness of the older people who participated in the exercise program with the Thai recreational sport “Jik Sen” was improved after the experiment in almost every test item. It is because the exercise program with the Thai recreational sport “Jik Sen” allows older people to have continuous physical activity. For this reason, participating in this exercise program continuously and for a sufficient period of time may result

in improved overall physical fitness among older people. Although this study did not find any clear results of change, at least it can be primarily confirmed that participating in the exercise program with the Thai recreational sport "Jik Sen" developed by the research team can help maintain the physical fitness among older people in the elderly school.

The study results also showed that the older people in the experimental group were satisfied with the exercise program with the Thai recreational sport "Jik Sen" for older people in elderly schools developed by the research team at the highest level. Possibly, this developed exercise program is more of a sport than general exercise. That is, there are rules, regulations, and methods of playing, and judging for losing and winning. It is also safe and easy for older people to play. Moreover, both older men and women can play it together. These reasons may cause the older people in the elderly school to participate in the recreational activities. In addition, from the non-participant observation during the experiment, it was also found that during participation in the exercise program, most older people talked, smiled, laughed, gave encouragement, and built confidence to other players on their own team. Applause sounds are heard from time to time for their own and teammates' performance. They also participated in planning the playing strategies of their own team at all times to defeat the opposing team. The older people also said that they were proud of themselves when they won. During the game, they were also talking and exchanging opinions with each other, allowing them to have more interactions with others. As a result, they will not be lonely and the happiness level increase, affecting their long-term well-being. Moreover, another possible reason is that the recreational sport "Jik Sen" was developed from the Thai folk game in the past. Therefore, more than 80% of older person in the experimental group had experience playing this Thai folk game during their childhood. Therefore, the older people in the experimental group felt joyful as if they had gone back to the days of their childhood, leading to the feelings of love in the traditions and culture of the nation, which currently receives less attention. This is consistent with a study by Fidan (2023) which reported that patriotism had a positive effect on life satisfaction. The study also confirmed that people who can be considered patriots tended to have higher levels of life satisfaction. Therefore, if the recreational sport "Jik Sen" is promoted by relevant agencies to make it an alternative activity in elderly schools throughout Thailand, it may not only help preserve the Thai folk game to not disappear from the country, but also promote the successful operation of elderly schools as is the case in many countries (Artisa & Kirana, 2021; Ide et al., 2023; Wong et al., 2019).

Conclusions

It can be concluded that the exercise program with the Thai recreational sport "Jik Sen" for older people in elderly schools developed by the research team is suitable for use in the context of Thai elderly schools. That is, it is an exercise program that helps encourage older people in elderly schools to have more interactions with others. It also helps promote thinking and planning skills and enjoyment. In addition, it is highly safe. It can be played indoors. Regarding the development of physical fitness, it can help improve agility and dynamic balance among older people.

Recommendations

Recommendations for the Implications of the study:

1. Public health personnel can apply the exercise program with the Thai recreational sport "Jik Sen" developed by the research team, such as adjusting the format to be played in single or pairs or increasing/decreasing playing materials (rubber rings) for players or reducing the playing duration to be appropriate for the health of older people they are responsible for.
2. The use of the exercise program with the Thai recreational sport "Jik Sen" should be expanded to the elderly group who do not participate in elderly school activities, such as those living in nursing homes or under the care of private elderly care facilities.

Recommendations for further research:

1. This study was conducted only over an 8-week period. Therefore, a long-term study should be conducted because changes in some physical fitness variables may be found.
2. An experimental study on the effects of participating in the exercise program with the Thai recreational sport "Jik Sen" for older people on variables other than physical fitness, such as thinking and planning skills, happiness level and quality of life should be conducted.

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Conflict of interest

The author declares that no conflicts of interest.

References

- Department of Economic and Social Affairs (2023). *World Social Report 2023: Leaving No One Behind In An Ageing World*. New York, United Nations publication.
- Department of Older Persons (2023a). *Situation of The Thai Older Persons 2023*. Bangkok, Amarin Corporations Public Company Limited. <https://thaitgri.org/?p=40218>
- Teerawichitchainan, B., Chayovan, N., & Knodel, J. (2020). Elder Abuse and Neglect in Thailand: Magnitude, Risk Factors, and Underlying Circumstances. *Journal of Elder Abuse & Neglect*, 32(2), 161-184. <https://doi.org/10.1080/08946566.2019.1644926>
- Thaithatkul, P., Chalermpong, S., Laosinwattana, W., & Kato, H. (2022). Mobility, Activities, and Happiness in Old Age: Case of the Elderly in Bangkok. *Case studies on transport policy*, 10(2), 1462-1471. <https://doi.org/10.1016/j.cstp.2022.05.010>
- Ladavanich, S., & Chalangkumdee, T. (2016). Understanding poverty among the elderly in Thailand. *Asian Population Studies*, 12(3), 270-290. <https://doi.org/10.1080/17441730.2016.1207841>
- Department of Elderly Affairs (2023). *Situation of the Thai elderly 2022*. Bangkok, Amarin Corporations Public Company Limited. <https://thaitgri.org/?p=40208>
- Department of Older Persons (2017). *Seniors School Guide*. Bangkok; Department of Older Persons, Ministry of Social

- Development and Human Security*.
<https://www.dop.go.th/th/known/5/197>
- Charoenwisal, R., & Dhammasaccakarn, W. (2022). Ageing society development strategy from a marginalised elderly group in Southern Thailand. *Development in Practice*, 33(8), 1-13. <https://doi.org/10.1080/09614524.2021.2013775>
- Kulachada, S., & Mitchell, C. (2019). Active ageing and the University for the Elderly: A case study from Thailand. *Journal of Applied Gerontology*, 38(1), 95-114. <https://doi.org/10.1177/0733464816676497>
- Ratana-Ubol, A. (2021). Lifelong Learning for Senior Citizens in Thailand. In: Narot, P., Kiettikunwong, N. (eds) *Education for the Elderly in the Asia Pacific. Education in the Asia-Pacific Region: Issues, Concerns and Prospects*, 59. Springer, Singapore. https://doi.org/10.1007/978-981-16-3326-3_7
- Department of Older Persons (2023b). *Schools for the elderly in Thailand* (February 2023). Retrieved December 27, 2023, from <https://www.dop.go.th/th/known/5/44> (In Thai)
- Aroonsrimorakot, S., Laiphrakpam, M., Metadilogkul, O., & Sharma, A.R.S. (2022). Interventions to reduce the negative impact of ageing, social isolation, and loneliness on the health and well-being of elderlies in Thailand and India. *Journal of Public Health and Development*, 20(2), 183-195. <https://doi.org/10.55131/jphd/2022/200214>
- Cohen-Mansfield, J., Marx, M. S., Dakheel-Ali, M., Regier, N. G., & Thein, K. (2019). The impact of stimuli on affect in persons with dementia. *Journal of Alzheimer's Disease*, 67(4), 1345-1356.
- Wang, H. X., Jin, Y., Hendrie, H. C., Liang, C., Yang, L., Cheng, Y., & Unverzagt, F. W. (2016). Late life leisure activities and risk of cognitive decline. *Journal of Gerontology Series A: Biomedical Sciences and Medical Sciences*, 71(12), 1594-1600.
- Kaewsuphan, W., Popa, A., Maneesakprasert, S., Meeton, A., & Pimboon, B. (2023). Health Behavior and Recreational Activity of Elderly People in Elderly Schools of Thailand. *Universal journal of public health*, 11(1), 27-33. <https://doi.org/10.13189/ujph.2023.110104>
- Asante, E., & Sam, A.W. (2022). The Legend of Aku Sika: A Transposition of Folk Narrative to a Stage Play. *International journal of studies in English language and literature*, 10(2), 15-24. <https://doi.org/10.20431/2347-3134.1002002>
- Choi, S.C., & Park, S.B. (2022). Exploring the educational values of Korean folk play and the revitalizing strategies in Elementary school. *Korean Association For Learner-Centered Curriculum And Instruction*, 22(24), 1047-1061. <https://doi.org/10.22251/jlcci.2022.22.24.1047>
- Ramani, B. (2022). Folk Playing Songs used in Kalangkurichi of Salem District- Psychological Thoughts. *International Research Journal of Tamil*, 4(S-16), 179-185. <https://doi.org/10.34256/irjt224s1623>
- Thu, T.L. (2022). Design music games based on the play of folk games to create excitement for preschool children 5 – 6 years old. *Journal of Science, Educational Science*, 67(4A), 237-246. <https://doi.org/10.18173/2354-1075.2022-0110>
- Hnawinchot, R., Wongsing, N., & Boonyasopun, U. (2019). Traditional Thai Games: Their Historical Background, Cultural Value, and Changes Over Time. In *2019 IEEE 3rd International Conference on Science and Systems (ICSS)* (pp. 383-388). IEEE. <https://doi.org/10.1109/ICSS47716.2019.9005984>
- Sangiamvibool, P., & Chommanee, W. (2020). The Importance of Traditional Thai Games in Promoting Physical Activity and Health of Children. *Journal of the Medical Association of Thailand*, 103(10), 1113-1120.
- Tangsirirup, K., & Butsatorn, P. (2020). The Revitalization and Sustainable Development of Traditional Thai Games in the Digital Age. In *2020 IEEE 11th International Conference on Awareness Science and Technology (iCAST)* (pp. 58-63). IEEE. <https://doi.org/10.1109/iCAST49983.2020.9280653>
- Thonglong, T., & Bussamongkhon, P. (2022). The Effect of Thai Traditional Play Program on Speed and Agility in Male Students in the Upper Primary School. *Trends in Sciences*, 19(17), 5764-5764. <https://doi.org/10.48048/tis.2022.5764>
- Komararat, C. Kerdkaew, F. & Laxanaphisuth, P. (1984). *Thai traditional sports: A study and analysis value in physical education*. Bangkok, Chulalongkorn University. (In Thai)
- Tongterm, T. (2013). *Folk games to promote health and complete humanity in a multicultural society (Research Report)*. Sisaket, Sisaket Rajabhat University. (In Thai)
- Tongterm, T., Pongthanu, M., Chimphali, K., Pengseesang, T., Sansak, K., & Kaewma, J. (2023). Jik Sen: The Development of Thai Folk Play to Recreational Sport for Youth. *National Academic Conference 2023 (9-11 August 2023)*. (pp. 124-143). Thai Association for Health, Physical Education and Recreation. (In Thai)
- Duan Yai Administrative Organization (2022). *Recording form for students at Duan Yai Rom Pho Thong School*. Sisaket, Duan Yai Administrative Organization. (In Thai)
- Faul, F., Erdfelder, E., Buchner, A., & Lang, A.G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, 41, 1149-1160. <https://doi.org/10.3758/BRM.41.4.1149>
- Petchalalai, C., & Udompanich, S. (2019). Effect of elastic band exercise program on physical performance in Thai elderly. *KKU Journal for Public Health Research*, 12(2), 52-61. (In Thai)
- Rikli, R.E. & Jones, C.J. (1999a). Functional fitness normative scores for community-residing older adults, ages 60-94. *Journal of Aging and Physical Activity*, 7, 162-181. <https://doi.org/10.1123/japa.7.2.162>
- Rikli, R.E. & Jones, C.J. (1999b). The development and validation of a functional fitness test for community-residing older adults. *Journal of Aging and Physical Activity*, 7, 129-161. <https://doi.org/10.1123/japa.7.2.129>
- Shonkoff, J.P., Richter, L., van der Gaag, J., & Bhutta, Z.A. (2016). An integrated scientific framework for child survival and early childhood development. *Pediatrics*, 138(2), e20160212.
- Rezwan, A.K.M, Hasnat, A., Rafiq, M.G., Ahamed, F., Jahangir, R., & Barua, D. (2022). Patients Satisfaction Level About Physiotherapy Service in Different Rehabilitation Center of Dhaka City- A Cross Sectional Survey Based Study. *International Journal of Research Publication and Reviews*, 3(6), 2188-2193. <https://doi.org/10.55248/gengpi.2022.3.6.32>
- Adliah, F., & Rini, L.S. (2023). Effects of Balance and Strength Tele-Exercise (BAST) on Muscle Strength and Functional Mobility in Older Adults. *Sandi Husada: Jurnal Ilmiah Kesehatan*, 12(1), 25-32. <https://doi.org/10.35816/jiskh.v12i1.858>
- Martini, N.M., Sari, N.L.P.D.Y., & Darmaja, K. (2022). Meningkatkan Kemampuan Kader Posyandu Lansia melalui Penerapan Latihan GELASE (GERAKAN BALANCE EXERCISE). *Dinamisia*, 6(6), 1565-1571. <https://doi.org/10.31849/dinamisia.v6i6.10517>

- Vittala, G., & Setiawan, C. (2023). The effectiveness of adding dynamic stretching exercises to balance strategy exercises in improving balance in the elderly. *Gaster: Jurnal Ilmu Kesehatan*, 21(1), 100-113. <https://doi.org/10.30787/gaster.v21i1.1066>
- Hemachithra, C., & Booshaa, S.R. (2022). Effect of otago exercise programme(oep) on balance and functional mobility among elder people in rural population. *Paripex - Indian Journal of Research*, 144-146. <https://doi.org/10.36106/paripex/3509206>
- Malasari, S., Sutriani, S., & Irwan, A.M. (2022). Balance Exercise Improves Muscle Strength And Body Stability In Frail Older People. *Majalah Keperawatan Unpad*, 5(1), 12-20. <https://doi.org/10.24198/jnc.v5i1.34837>
- Rusminingsih, E., Marwanti, M., Sawitri, E., & Cahyani, A.D. (2021). The Effect of Balance Exercise (Forward Stepping) on The Risk of Falling in the Elderly. *Urecol Journal.Part C: Health Sciences*, 1(1), 24-29. <https://doi.org/10.53017/UJHS.43>
- Shier, V., Trieu, E., & Ganz, D.A. (2016). Implementing exercise programs to prevent falls: systematic descriptive review. *Injury Epidemiology*, 3(1), 16. <https://doi.org/10.1186/s40621-016-0081-8>
- Fidan, A. (2023). The Impact of Patriotism and Religiosity on Life Satisfaction. *Iğdır üniversitesi sosyal bilimler dergisi*, 32, 341-357. <https://doi.org/10.54600/igdirsosbilder.1196077>
- Artisa, R.A., & Kirana, C.A. (2021). Happy Elderly Through Elderly School: Collaboration in Empowering Elderly in Bandung City. *Journal of Government and Political Studies*, 4(1), 119-127. <https://doi.org/10.32662/GJGOPS.V4I1.1376>
- Ide, K., Hayashi, T., Abe, N., Nakagomi, A., & Kondo, K. (2023). Association between social participation and frailty among older adults: a longitudinal study from Japan Gerontological Evaluation Study. *Japanese journal of public health*, 70(9), 529-543. <https://doi.org/10.11236/jph.22-088>
- Wong, E.Y.S., Lee, A.H., James, A.P., & Jancey, J. (2019). Recreational Centres' Facilities and Activities to Support Healthy Ageing in Singapore. *International Journal of Environmental Research and Public Health*, 16(18), 3343. <https://doi.org/10.3390/IJERPH16183343>

Тайська народна гра «Джік Сен» набула статусу рекреаційного виду спорту для осіб похилого віку в школах даної категорії населення

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

Реферат. Стаття: 11 с., 5 табл., 10 рис., 44 джерела.

Мета дослідження. Мета цього дослідження була спрямована на реалізацію наступних завдань: 1) розробити програму вправ, що включає заняття з тайського рекреаційного виду спорту «Джік Сен» для осіб похилого віку в школах цієї категорії населення; 2) дослідити вплив програми вправ з тайського рекреаційного виду спорту «Джік Сен» на показники фізичної підготовленості літніх людей в школах даної категорії населення; 3) оцінити рівень задоволеності осіб похилого віку програмою вправ для занять з тайського рекреаційного виду спорту «Джік Сен».

Матеріали та методи. Проведено двогрупове експериментальне дослідження, що складалося з експериментальної групи в кількості 17 осіб (65,53 ± 3,43 років) та контрольної групи до якої було залучено також 17 осіб (65,76 ± 3,60 років). У дослідженні брали участь люди з добрим станом здоров'я віком від 60 років і старше, які активно займалися за програмою школи для літніх осіб. Для відбору учасників використовувався метод цілеспрямованої вибірки, після чого вони були розподілені на експериментальну та контрольну групи за допомогою методу зіставлення на основі індексу маси тіла. Інструменти дослідження охоплювали програму вправ, що включала тайський рекреаційний вид спорту «Джік Сен», розроблений дослідницькою групою, а також тест на визначення рівня фізичної активності для осіб похилого віку (SFT – Senior Fitness Test). Впродовж 8 тижнів експериментальна група виконувала програму вправ, що складалася з 60 хвилин щоденних тренувань з тайського рекреаційного виду спорту «Джік Сен», з частотою занять 3 дні на тиждень. Контрольний груп було доручено дотримуватися свого звичного розпорядку дня і не брати участі в жодних фізичних навантаженнях або програмах тренувань під час експерименту. Отримані дані проаналізовано із використанням середнього значення, стандартного відхилення, відсоткового співвідношення та t-критерію.

Результати. 1) Програма вправ, що включає тайський рекреаційний вид спорту «Джік Сен» для осіб похилого віку в школах даної категорії населення, може бути належним чином застосована з метою популяризації фізичних вправ і спорту в навчальних закладах для літніх людей в Таїланді. Значення ІОС становило 0,97. 2) Спостерігалася достовірні різниця в середніх балах у виконанні тесту на визначення швидкості, спритності та рівноваги (учасники мали встати зі стільця, пройти якомога швидше відстань 2,44 м – 8 футів і знову сісти) між передекспериментальним (середнє = 7,94; SD = 1,34) та післяекспериментальним (через 8 тижнів) періодами (середнє = 6,70; SD = 0,79) у досліджуваних осіб експе-

риментальної групи на рівні 0,05. Середні бали тесту при вставанні зі стільця та швидкості ходи на відстань 8 футів між контрольною групою (середнє = 7,84; SD = 1,16) та експериментальною групою (середнє = 6,70; SD = 0,79) також показали значну різницю на рівні 0,05. 3) Експериментальна група висловила високий рівень задоволеності програмою вправ з тайського рекреаційного спорту «Джік Сен» для осіб похилого віку в школах даної категорії населення із середньою оцінкою $4,62 \pm 0,51$ бала.

Висновок. Програма вправ, що включає заняття з тайського рекреаційного виду спорту «Джік Сен», сприяє ефективному покращенню динамічної рівноваги осіб похилого віку в школах для даної категорії населення. Крім того, було доведено, що така форма фізичної активності полегшує соціальну взаємодію, поліпшує когнітивні здібності, включаючи навички мислення і планування, а також сприяє отриманню задоволення від життя.

Ключові слова: школи для осіб похилого віку, літні люди, фізична підготовленість, рекреаційний вид спорту, тайська народна гра.

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Ascertaining the Peculiarities of Athletes' Adaptation Course to Post-Sports Life

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Abstract

Objectives. The purpose of the study was to identify the peculiarities of athletes' adaptation to post-sport life under modern conditions of reality.

Materials and methods. The study involved 36 athletes, Masters of Sports, aged 25 to 40 years, who had finished their professional sports careers in disciplines such as ballroom dancing, artistic gymnastics, football, swimming, and judo. The study used methods of analysis and generalization obtained from scientific-methodical literature and internet data, surveys, and psychodiagnostics: the "Differential Emotions Scale" by C. Izard, adapted by A. Leonova, the "Meaningful Life Orientations" method by D. A. Leontiev, an adapted version of the "Purpose-in-Life Test" (PIL) by James Crumbaugh and Leonard Maholick, as well as the "Zimbardo Time Perspective Inventory" (ZTPI) by Zimbardo, P. G., & Boyd, J. N. During the study results' analysis, the following methods were used: frequency analysis – identification of the frequency of each emotion category (absolute frequencies), and a calculation of percentage values (relative frequencies) for each category relative to the total number of participants. This was also applied to determine the number of athletes belonging to each category of future plans and to define the components of the time perspective; descriptive statistics – calculation of the mean value for each survey scale; these values were used to compare mean values between different scales and to analyze the variability of responses by calculating the standard deviation; percentage calculation.

Results. This study examined the post-sport adaptation of 36 athletes using psychodiagnostic methods, thereby uncovering a complex emotional landscape and a variety of future perspectives. The survey results showed that 43 % of the respondents had not yet decided what they wanted to become in their post-sports life, indicating significant stress, negative emotions, and physical and psychological problems that require attention and support. A significant portion (40 %) of respondents affirmed that they could envisage their future without sports, with 25 % choosing to become coaches and 15 % interested in sports-related professions. Only 17 % of respondents considered their future in other fields. The study also found that 42 % of athletes reported having a strongly negative attitude towards leaving professional sports, experiencing feelings such as despair, grief, anger, disgust, and confusion. Another 36 % of athletes characterized their emotional state as anxious-depressive, which also requires attention. Meanwhile, 22 % of respondents stated a positive emotional attitude towards ending their careers, demonstrating interest in new circumstances and their future, which helps them to transition effectively into new lives. The study results on life orientations revealed that athletes tended to be more focused on past achievements and current goals than on the future, which may complicate their adaptation to post-sports life. Nevertheless, 37 % of athletes are oriented towards a positive future and are willing to make efforts to achieve the necessary goals. Therefore, the findings clearly indicate the need for post-sports support and increased attention to the large proportion of former athletes (79 %), whose mental health depends on the timeliness and speed of measures taken by specialists.

Conclusions. The transition process for athletes after ending their professional careers to a life without sports is defined as individually nuanced, complex, and prolonged; it depends on past career success, is accompanied by stressful situations and negative emotions, and often requires a sudden conclusion to preserve the sense of being a champion.

Keywords: athletes, adaptation, post-sport life, professional career, psychodiagnostics.

Introduction

The adaptation of qualified athletes to life after the end of their sports careers has always been a pertinent issue. Its importance is further underscored by the fact that the process of adapting to a life without strict self-discipline, the customary constant physical and mental loads for athletes, stressful situations during competitions, and the experience of inspiration and pride in victory depends on many important factors: the athlete's age, the reason for ending their career, level of qualification, type of sport, etc. Arabadzhy (2009), has shown that a longer professional career is observed in track and field athletes, skiers, representatives of team sports, and wrestlers. Evans et al. (2012), Shynkaruk et al., (2022) note in their research that intense physical and mental loads are an integral part of an athlete's activity, which determine the success of their achievements, and a reduction or absence of such a rhythm of life after stopping daily sports activities, changes in the body's functioning conditions, lead to health hazards for the athlete.

The adaptation of qualified athletes to life after the end of a sports career has always been a relevant issue. Its importance is further mediated by the fact that the process of adaptation to life without strict self-discipline, the usual constant physical and mental stress, stressful situations during competitions, experiencing feelings of inspiration and pride in victory, depends on many important factors: the athlete's age, the reason for ceasing activity, the level of qualification, the type of sport, etc. Thus, as Arabadzhy (2009) proved, a longer professional career is observed in athletes, skiers, representatives of team sports, and wrestlers. Evans et al. (2012), and Shynkaruk et al. (2022) in their studies note that heavy physical and mental loads are an integral part of an athlete's activity, on which the success of his achievements depends, and a reduction or absence of such a rhythm of life after the end of daily sports activities, changing the conditions of the body's functioning, lead to dangerous health phenomena in the athlete's body.

Unfortunately, both athletes and coaches during active sports activities do not always realize the importance of the aforementioned problem and do not think about ways to solve it. The reasons for this are usually associated with the constant busyness of athletes due to intensive training and competition schedules, a hidden hope to stay active for a long time, that "this cannot happen to me", and the desire of the coach not to remind unnecessarily about the inevitability of ending a sports career in order for the athlete to stay in sports as long as possible. This is identified by researchers Voronova et al. (2020), Shynkaruk, Skalozub, Davydov et al. (2023) in their studies.

As Brooke Howard-Smith (2017) notes, with the approach of the final stage of the sports career, it is necessary to remember that this is the last opportunity when athletes and coaches still have the chance to take certain steps, forecast and eliminate various unwanted crisis situations, and prepare for them in advance. This is important considering that the timeliness of the athlete's problem-solving at this stage largely determines his overall satisfaction with the entire sports career in general and the success of his further career beyond active sports activity.

An integral part of the onset of post-sport life without active sports involvement is its stressful nature. The entire way of life to which an athlete has become accustomed over

many years changes, and typically, starting from physical and functional to psychological components of this process, the athlete's body is not ready for such maladaptive changes. Konevskikh et al. (2013), and Marchenko (2022) determine the criteria for maladaptive changes to be a combination of various disturbances in the psycho-emotional, somatic, and social components of the athlete's life, indicating the need for a comprehensive combination of scientific knowledge in physiology, medicine, psychology, and sociology when studying post-sport adaptation issues.

As for the consequences, few athletes manage to cope with the change in many of the usual rules of their past activities without significant loss. Another factor negatively affecting an athlete's adaptation after the end of their career, as identified by Bouchetal et al. (2006), is the particularly traumatic reaction of athletes to this process, who typically enter sports at a young age, since it is known that the path to professional sports career beginnings is significantly shifted to the early years of an individual's life. Consequently, a sports career is perceived as something infinite, constant, and fundamental in an athlete's life.

If the transition process arises suddenly, unplanned, and not gradually, and at the same time, the surroundings (coaches, parents, friends) do not see any particular problems in it and do not consider it necessary to materially or psychologically assist the athlete, such a transition will be stressful, very painful, and significantly harmful. During this period, as noted by Fricker (2013), the reaction of not only the immediate environment is important, but also the influence of the social and cultural norms existing in the athlete's native country, which the athlete absorbed during growth and upbringing, as the basis of their personal morality.

Clark (2009) points out that during this acute transition period, the most common issues related to losses of mental stability are a sharp decrease in self-esteem, increased anxiety, and the emergence of depressive states, which in turn leads to a disruption in the sense of identity and stress. At the same time, during relevant surveys, athletes who are saying goodbye to active sports note their own confusion, loss of self-confidence, severe depression, as they do not understand what will happen to them next and where their life path will turn.

The purpose of the study was to identify the peculiarities of athletes' adaptation to post-sport life under modern conditions of reality.

Materials and Methods

Participants

The study involved 36 athletes, masters of sports, aged 25 to 40 years, who had finished their professional sports careers in disciplines such as ballroom dancing, artistic gymnastics, football, swimming, and judo.

Study Organization

The study used methods of analysis and generalization of scientific-methodical literature and internet data, surveys, and psychodiagnostics.

The survey of 36 athletes was aimed at determining the athletes' vision of their future, plans after the end of their professional careers. The main questions identified were:

establishing athletes' opinions on the period of active sports involvement, their sports specialization and qualifications, the most significant success in their professional careers, and the presence of plans for life after ending their career as an active athlete.

Psychodiagnostics Included

The "Differential Emotions Scale" by Izard (2000), adapted by A. Leonova – determined the degree of the subject's leading emotional attitude to the current situation, characteristic of him in various life situations, in our case, to the situation of ending a sports career and further adaptation to a new life. The participant chose a certain one of the 10 basic emotions, presented by three different concepts, which imply the illumination of various shades of emotional experiences. This is achieved by the athlete's assessment of the strength of the corresponding experience in a particular situation of professional formation during sports activities. Materials and methods.

The "Meaningful Life Orientations" method by D. A. Leontiev, an adapted version of the "Purpose-in-Life Test" (PIL) by James Crumbaugh and Leonard Maholick (Leontiev, 2011), was used to determine the main goal in an athlete's life, which can be fixed by them in three temporal dimensions: the future (goals), the present (process), the past (outcome), or in all three aforementioned components of the athlete's life. In this particular study, the focus was on the period after the end of the sports career. The Meaningful Life Orientations method consists of twenty pairs of opposite statements reflecting the factors of meaningfulness in an athlete's personal life. There are five subscales that characterize three specific life meaning orientations (goals in life, life richness, and self-fulfillment satisfaction) and two aspects of locus of control (self-locus of control and life-locus of control). The method treats life as meaningful in the presence of goals and the satisfaction achieved in their accomplishment, confidence in one's own ability to set goals, choose tasks from those available, and achieve results. During the diagnostics process, the definition of the situation gives each individual the opportunity to make a certain choice in the present in the form of an act, action, or inaction. The basis of such a choice is a formed notion about the meaning of life or its absence.

The theoretical concept underlying the "Zimbardo Time Perspective Inventory" (ZTPI) by Zimbardo and Boyd (1999) provides a means to integrate motivational, emotional, cognitive, and social processes in an individual's life space. This methodology allows for the assessment of individual differences in time profiles and specific time orientations through a selection from five scales, offering a comprehensive outline of time perspective due to its reliable psychometric properties (clear factorial structure, high levels of reliability, validity, and the ability to assess different dimensions of time perspective). The self-realization of athletes after the end of their sports career involves the activation of an individual's readiness for self-development of their own potential, and the realization of their talents and possibilities. Such activation requires examining the main components of perspective: two aspects of the attitude towards the past—a negative past (seen as unpleasant, causing aversion), a positive past (past experiences are seen pleasantly, through 'rose-colored glasses', accompanied by nostalgia), hedonistic present—

filled with pleasures valued above all, enjoyment of the current moment, without consideration for future actions, deeds, behavior. In relation to the future, only one aspect is highlighted—future orientation, which is characterized by the presence of goals, plans aimed at the future, and behavior directed towards their realization.

Statistical Analysis

During the analysis of the study results, the following methods were used:

Frequency analysis:

Identification of the frequency of each emotion category (absolute frequencies).

Calculation of percentage values (relative frequencies) for each category relative to the total number of participants.

The formula for calculating the percentage frequency (P) of each index:

$P = (\text{Number of athletes in the category} / n) \times 100$, where n – is the total number of participants (in this case, 36).

For example, for the index of positive emotions (IPE): $IPE = (8/36) \times 100 = 22\%$.

This was also applied to determine the number of athletes belonging to each category of future plans and to define the components of the time perspective.

Descriptive statistics: calculation of the mean value for each survey scale.

These values were used to compare mean values between different scales and to analyze the variability of responses by calculating the standard deviation.

Percentage calculation: the percentage of athletes for each category was determined relative to the total number of respondents.

Results

To determine the peculiarities of the adaptation process of athletes to post-sport life under modern conditions, 36 athletes were surveyed and studied using psychodiagnostic methods. The survey results regarding the athletes' plans for the future after ending their active careers indicate that 43 % of them have not yet decided what they want to become in their post-sport life. This group represents the contingent for whom the transition period may be accompanied by stress, negative emotions, physical and psychological problems, and who requires significant attention and support (Fig. 1).

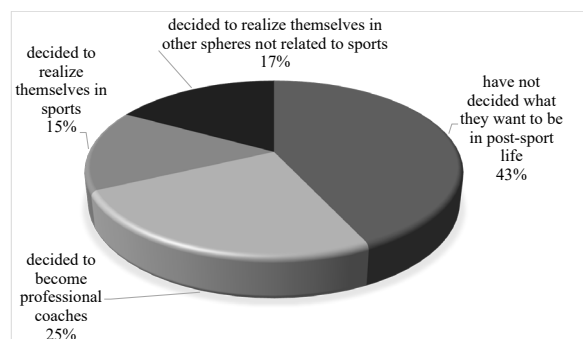


Fig. 1. Results of the survey conducted to study the future plans of athletes after the end of their active careers (n = 36)

A significant portion (40 %) of the respondents still cannot envision their future without sports, hence 25 % of them have decided to choose a coaching profession within their sport; 15 % expressed interest in professions that are somehow related to sports. Only 17 % see their future in other areas not related to sports.

An important aspect in the process of gradually transitioning to activities without active involvement in a particular sport is its emotional component, as there is no athlete who would gladly and without negative feelings leave the activity to which they have devoted their life, predominantly from early childhood. Therefore, one of the important issues addressed in this study was to determine the level of the leading emotional attitude of the participants towards the situation of ending their sports career and further adaptation to a new life using the "Differential Emotions Scale" by C. Izard, adapted by A. Leonova, which indicates the following identified features (Table 1).

Table 1. Results of the study using the "Differential Emotions Scale" by C. Izard, adapted by A. Leonova (n = 36)

Emotional Indicator Before the End of Sports Career	Number of Athlete	
	Abs.	%
Index of Positive Emotions (IPE)	8	22
Index of Acute Negative Emotions (IANE)	15	42
Index of Anxious-Depressive Emotions (IADE)	13	36
Total	36	100

The largest group of athletes emerged whose attitude towards the necessity to leave professional sports activities was sharply negative – 42 %. The range of emotions they reported experiencing includes despair, sorrow, anger, disgust, and confusion.

Additionally, the attitude towards the situation by 36 % of respondents can be considered negative, with their emotions characterized as anxious-depressive. Such negative experiences often feature vivid individual manifestations that accompany the subjective attitude towards the current situation.

The highlighted results of the study clearly indicate the need for post-sport support and heightened attention to a large portion of former athletes (79 %), whose mental health depends on the timeliness and speed of measures taken by specialists.

However, it is necessary to note the 22 % of respondents whose, apparently, optimistic character and attitude towards life lead to a positive emotional attitude towards the end of their sports career. The characteristic coloring of the emotions of such subjects is an interest in new circumstances and a curiosity about their future, which will undoubtedly facilitate an effective entry into a new life for them, quick search, and assimilation of a new type of activity.

The survey results regarding the respondents' vision of their place in post-sport life logically led to addressing the next task, namely, which goals prevail in the lives of the athletes we surveyed in the past, how they perceive the priorities of their current life, and how, in their understanding, the outcomes of the past, present, and future correlate (Table 2).

The study of such life meaning orientations revealed low scores (23.72), indicating an awareness of the goals and tasks

Table 2. Survey results using the "Life Meaning Orientations" method by D. A. Leontiev (n = 36)

Scale	Average Score, Points
Goals in Life	23.72
Life Process	30.61
Effectiveness	20.25
Self Locus of Control	23.44
Life Locus of Control	31.67

facing the participants. However, in this awareness, past events and current goals are prioritized, with a lack of necessary concern for the future day and planning necessary measures for it. These results, in our opinion, suggest that even after the end of their professional career, the lives of athletes continue to be dominated by habits and skills formed depending on the specifics of sports life: a focus on achieved victories, the belief in the need to increase training loads to improve performance, and faith in the decisive word and help of a coach.

This is confirmed by the results obtained by participants when studying the degree of interest in their present life, its emotional and meaningful saturation. The obtained average score, namely 30.61, gives reason to perceive the present period of their life as interesting and emotionally rich but not quite satisfying their expectations. Given the above and typically high level of aspirations that inexorably pushed the athlete to constantly strive for the best results in the past, the obtained indicator is understandable. This is also confirmed by the score aimed at determining self-realization satisfaction – 20.25 points, which gives us a reason to point out the participants' dissatisfaction with their past life, confusion in the present from no longer having to think about achievements and improving results as they usually did, but still harboring hope that the application of existing skills and abilities will be useful to them in the future.

The presence of such hope is also indicated by the score reflecting the level of self-locus of control – 23.44 points. This quality is a crucial component of success in any sport as it ensures the ability to constantly monitor one's own state, behavior, and actions. Undoubtedly, this ability in athletes, which can be considered an indicator of professional mastery, is not innate but is developed and reinforced based on the specific training and competitive characteristics of sports activities. Depending on their personal psychological traits, athletes, influenced by years of sports practice, may differently attribute the causes of significant events, situations, and moments in their activities, either externally (external locus of control) or internally (internal locus of control).

Thus, just as in their sporting life, having been accustomed to being accountable for themselves and their results, athletes who have ended their careers in professional sports will clearly understand the necessity to manage all aspects of their own lives. Such statements are substantiated given the score obtained during the study for the locus of control over one's own life (31.76 points).

Although this indicator may decrease in cases of the athlete experiencing stress, anger at their own failures, fatalism, the impossibility of freedom of choice, uncertainty about the future, which, as already mentioned, are acute characteristics of the transition period from the professional life of an athlete to life outside sports.

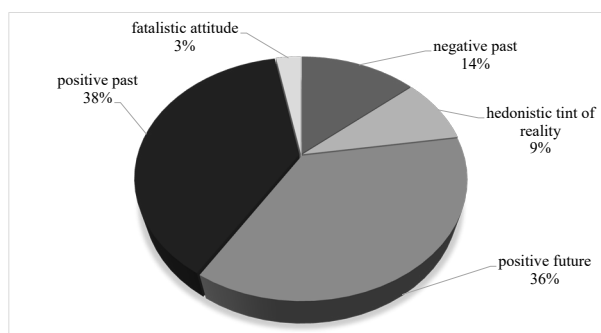


Fig. 2. Distribution of respondents' thoughts based on the survey results using the "Zimbardo Time Perspective Inventory" by P. Zimbardo, (n = 36)

The determination of the components of time perspective revealed the following characteristics, presented in Figure 2.

14 % of the respondents negatively assess their past life in sports, which can be explained by some very unpleasant events in their professional life that have left a mark in their consciousness and become an internal personal anxiety symptom (defeats, low rankings in competitions, frequent injuries, not being included in the main team lineup, etc.).

39 % of the athletes participating in the study express a pleasant, sentimental attitude towards the past, with a hint of nostalgia.

9 % of the participants note a hedonistically colored, significant importance for their life here and now, where the tension, elevation during the optimal state of combat readiness and after victory, feelings of glory, superiority over others, and being a winner become an integral part of their experience without which they cannot imagine their future life.

37 % of the surveyed in the research process are oriented towards a positive future and are ready to make efforts to achieve necessary goals, which will be facilitated by the combative character developed in sports, competitive spirit, and competitive aggression.

3 % of the respondents are characterized by a fatalistic attitude towards what is happening to them today, hence they feel lost, helpless, and believe that nothing depends on them because their fate is controlled by some other forces, on which the future events of their life depend.

Discussion

The main hypothesis of the study is that the adaptation of qualified athletes to life after the end of their sports career is a complex and stressful process that requires comprehensive support to ensure a successful transition.

The results of the survey conducted among 36 athletes, who faced the necessity of addressing the issue of parting with sports, indicate that 43 % of them have not yet decided what they want to become in their post-sports life. 40 % of respondents do not see their future without sports, of which 25 % chose the profession of a coach, and 15 % are interested in professions related to sports. 17 % of athletes see their future in other fields. The largest group was former athletes who had a strongly negative attitude towards the necessity of leaving professional sports – 42 %. Another 37 % of respondents showed anxious-depressive emotions. Arabadzhy (2011) indicates that the crisis associated with the end of a sports

career is most acute when it arises suddenly, the athlete is unprepared for it, and there is a lack of multifaceted support.

Herzog's (1994) research emphasizes the traumatic and complex nature of premature forced career termination, highlighting the need for special organizations to support the transition process from active sports to post-sports life. This need is explained by the presence of psychological disorders in athletes, mental health issues (depression, grief, loss of identity, low self-esteem, communication issues, thoughts of losing the future and control over it, uncertainty in professional self-determination, emotional disorders, deviant behavior, and the formation of various dependencies). This is confirmed by the studies of Evans et al. (2012), and Guo, J. (2009).

One of the most acute characteristics of the post-sports transition is the forced end of a long career due to a hard-to-recover injury or refusal of choice rather than a conscious decision. Bouchetal et al. (2006), Guo (2009), Herzog (1994) note that identity issues, accompanied by a sharp decline in self-esteem and the appearance of uncertainty, arise when the injury is severe enough to lead to an exit from sports.

Lavallee et al. (2024) identified three key factors significant for conscious adaptation management. The first factor includes the reasons for stopping sports and the degree of possible control over this process, as a conscious decision greatly facilitates the transition. The second factor emphasizes the importance of multifaceted support for the athlete, ensuring the involvement of various resources to successfully overcome the challenges of the transition process, such as social, material, and psychological support (Shynkaruk, Skalozub, Yukhno et al. 2023). The third key factor points to the importance of considering identity issues, as an athlete often sacrifices many aspects of everyday life for high achievements, and after a sudden end, they may feel that all sacrifices were in vain.

The conducted survey indicates that the significance of the transition period is emphasized by all athletes. Beunen and Malina (1988) define that the specifics of this period vary: for mid-level athletes, its duration can be 6–12 months, while for elite athletes, it can be significantly longer. The success of adaptation depends on the level of achievements: the higher the sports achievements, the more difficult the social adaptation. Arabadzhy (2011) notes that highly qualified athletes often prefer a sharp end to their careers, aiming to remain undefeated champions. However, both elite athletes and lower-level athletes fully experience despair and psychological stress, requiring special attention from coaches, teammates, parents, and friends.

The presented results emphasize the importance of comprehensive support for athletes during the transition to post-sports life. It is crucial to consider both psychological and social aspects of this process to ensure a successful and smooth transition. This is confirmed by studies of Fricker (2013), Clark (2009), and others, highlighting the importance of support from family, friends, and society.

The practical application of the research results includes the development of support programs that help athletes cope with stress and adapt to new life. For example, a five-step career planning strategy can be used for gradual transition, considering personal circumstances and the needs of each athlete. This can reduce stress levels and ensure a smooth transition to new activities. The "IOC Athletes' Career Programme," adopted by the national Olympic committees of 35 countries, including Ukraine, is an example of a successful initiative that helps athletes in this process.

Further research should focus on improving existing support programs and developing new methods of adaptation, especially for athletes who have ended their careers due to injuries or other unexpected circumstances. It is also important to study the impact of various factors, such as cultural and social norms, on the adaptation process to ensure an individual approach for each athlete.

Conclusions

The transition process for athletes after ending their professional career to a life without sports is individually nuanced but universally challenging, prolonged, and accompanied by stressful situations and negative emotions for all athletes. The process of social adaptation significantly depends on the level of success in their past professional career: the higher the sports achievements, the more difficult the social adaptation.

Highly qualified athletes who have achieved high sports results prefer to end their sports career abruptly, believing that it allows them to leave sports as undefeated champions.

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Conflict of interests

The authors state that there is no conflict of interests.

References

- Arabadzhy, T.D. (2009). On the peculiarities of the manifestation of an athlete's personality activity in professional self-determination. *Theory and Practice of Social Systems Management: Philosophy, Psychology, Pedagogy, Sociology. Collection of scientific works*. Kyiv-Vinnytsia, 4, 115-119. (In Ukrainian)
- Evans, L., Wadey, R., Hanton, S., & Mitchell, I. (2012). Stressors experienced by injured athletes. *Journal of Sports Sciences*, 30, 917-927. <https://doi.org/10.1080/02640414.2012.682078>
- Shynkaruk, O., Voronova, V., Shevtsova, O., & Podolian, O. (2022). Motivation of the Player as a Factor in the Formation of a Career in Esports. *Innovative and Information Technologies in Physical Culture, Sport, Physical Therapy, and Ergotherapy: Materials of the V All-Ukrainian Electronic Scientific and Practical Conference with International Participation (Kyiv, May 31, 2022)* / ed. O.A. Shynkaruk. Kyiv: National University of Physical Education and Sports of Ukraine, pp. 158-160.
- Voronova, V., Khmel'nitska, I., Shynkaruk, O., Borysova, O., Kostyukevich, V., & Zhovnych, O. (2020). Gender Peculiarities of Personality's Qualities Development in Football. *Journal of Physical Education and Sport*, 20(1), 484-489. <https://doi.org/10.7752/jpes.2020.s1071>
- Shynkaruk, O., Skalozub, A., Davydov, D., Yakovenko, O., Fedorchuk, S., Shevtsova, A., Yukhno, Y., & Golovanova, N. (2023). The Significance of Psychological Preparation and the Role of a Psychologist in Ensuring the Effectiveness of Players in Esports. *Physical Culture, Sport and Nation's Health: Collection of Scientific Works*, 15, 381-394.
- Brooke Howard-Smith. (2017, February 21). *Athletes Die Twice – What is Athlete Identity Crisis and how it could connect recent rugby tragedies*. Available: <https://www.linkedin.com/pulse/athletes-die-twice-what-athlete-identity-crisis-how-howard-smith>
- Konevskikh, L.A., Oranskiĭ, I.E., & Makogon, I.S. (2013). The adaptive capacities of the cardiovascular system in miners exposed to vibration. *Med. Tr. Prom Ekol.*, 2, 32-37.
- Marchenko, H.Ye. (2022). *Features of adaptation to post-sport life of athletes*. [Master's thesis]. Kyiv: National University of Physical Education and Sports of Ukraine. 97 p. (In Ukrainian)
- Bouchetal, P.F., Leseur, V., & Debois, N. (2006). *Sportive Career. Life Project*. Paris: INSEP-Publications. (in French)
- Fricker, P. (2013). *Support services in athletic development: good practices from the field*. In P. Sotiriadou & V. De Bosscher (Eds.), *Managing high performance sport*. New York: Routledge, 183-204.
- Clark, J. (2009). *Olympic Athletes: the Pressures of Winning. XIII Olympic Congress*. Lausanne, Switzerland: International Olympic Committee, 546-547.
- Izard, C. (2000). *The Psychology of Emotions*. 464 p.
- Leontiev, D.A. (Ed.). (2011). *Personal Potential: Structure and Assessment*. 679 p.
- Zimbardo, P. G., & Boyd, J. N. (1999). Putting time in perspective: A valid, reliable individual-differences metric. *Journal of Personality and Social Psychology*, 77(6), 1271-1288. <https://doi.org/10.1037/0022-3514.77.6.1271>
- Leonova, A. B. (2007). Structural-integrative approach to the analysis of human functional states. *Bulletin of Moscow University. Series 14. Psychology*, 1, 87-103.
- Herzog, M. (1994). The athletes development, place, and role in society. *Centennial Olympic Congress Report*, 177.
- Guo, J. (2009). *Specific support for Athletes: the Earlier, the better*. XIII Olympic Committee, 551-552.
- David Lavalle, Paul Wylleman, Mayi Cruz Blanco, & Rick Echevarria. (2024). *Life after sport: Why Athletes need to prepare*. Available: <https://olympics.com/athlete365/whitepaper/life-after-sport-why-athletes-need-to-prepare/>
- Shynkaruk, O., Skalozub, A., Yukhno, Y., & Shevtsova, A. (2023). Psychological Preparation of Players and the Structure of Activities of a Sports Psychologist in Esports. *Theory and Methods of Physical Education and Sport*, 1, 84-90. <https://doi.org/10.32652/tmfvs.2023.1.84-90>
- Beunen, G., & Malina, R.M. (1988). Growth and physical performance relative to the timing of the adolescent spurt. *Exercise and Sport Science Reviews*, 16, 503-540. <https://doi.org/10.1249/00003677-198800160-00018>
- Arabadzhy, T.D. (2011). The necessity of forming professional self-determination in athletes. *Pedagogy, Psychology and Medical-Biological Problems of Physical Education and Sports. Collection of scientific works*. Kyiv-Vinnytsia, 11, 5-8. (In Ukrainian)
- Athlete Career Transition* (2024) Available: <https://www.athletecareertransition.com/>
- Career transition* (2024). Available: <https://olympics.com/athlete365/courses/career-transition/>
- What does career transition mean to us?* (2024) Available: <https://www.athletecareertransition.com/post/what-does-career-transition-mean-to-us>

Особливості перебігу адаптації спортсменів до постспортивного життя

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

Реферат. Стаття: 7 с., 2 табл., 2 рис., 24 джерела.

Метою дослідження було визначення особливостей адаптації спортсменів до життя після завершення спортивної кар'єри в умовах сучасної реальності.

Матеріали та методи. У дослідженні взяли участь 36 спортсменів, майстрів спорту, віком від 25 до 40 років, які завершили свою професійну спортивну кар'єру в таких дисциплінах, як бальні танці, художня гімнастика, футбол, плавання та дзюдо.

У дослідженні використовувалися методи аналізу та узагальнення науково-методичної літератури та даних мережі Інтернет, опитування та психодіагностика: шкала диференціальних емоцій К. Изарда в адаптації А. Леонової, методика «Смислоттєві орієнтації» Д. Леонтьєва, адаптована версія тесту «Цілі в житті» (PIL) Дж. Крамба та Л. Махоліка, «Інвентаризація часової перспективи Зімбардо» (ZTPI) П. Зімбардо, та Бойда, Дж. Н. Дослідженню підлягали: частотний аналіз – визначення частоти кожної категорії емоцій (абсолютні частоти), розрахунок процентних значень (відносні частоти) для кожної категорії стосовно загальної кількості учасників – застосовували для визначення кількості спортсменів, що належать до кожної категорії майбутніх планів; для визначення компонентів часової перспективи; описова статистика: розрахунок середнього значення для кожної шкали опитувальника, для порівняння середніх значень між різними шкалами, для аналізу варіативності відповідей шляхом розрахунку стандартного відхилення; розрахунок відсотків.

Результати. Досліджено адаптацію до постспортивного життя 36 спортсменів за допомогою психодіагностичних методів, виявляючи складний емоційний ландшафт та різноманітні перспективи майбутнього. Результати опитування показали, що 43 % респондентів ще не визначилися, ким хочуть стати в своєму постспортивному житті, що вказує на значний стрес, негативні емоції та фізичні і психологічні проблеми, які потребують уваги та підтримки. 40 % респондентів не бачать свого майбутнього без спорту, 25 % обирають стати тренерами, 15 % цікавляться професіями, пов'язаними зі спортом. Лише 17 % бачать своє майбутнє в інших галузях. 42 % спортсменів мають сильно негативне ставлення до завершення професійної спортивної кар'єри, відчують відчай, горе, гнів, огиду та збентеження. 36 % спортсменів характеризують свої емоції як тривожно-депресивні, що потребує уваги з боку фахівців. 22 % респондентів мають позитивне емоційне ставлення до завершення кар'єри, виявляють інтерес до нових обставин і свого майбутнього, що допомагає їм ефективно переходити до нового життя. Результати дослідження життєвих орієнтацій показали, що спортсмени більше орієнтовані на минулі досягнення та поточні цілі, ніж на майбутнє, що може ускладнити їхню адаптацію до постспортивного життя. Проте 37 % спортсменів орієнтовані на позитивне майбутнє та готові докладати зусиль для досягнення необхідних цілей. Отримані дані вказують на необхідність підтримки після закінчення спортивної кар'єри та підвищеної уваги до великої частини колишніх спортсменів (79 %), психічне здоров'я яких залежить від своєчасності та швидкості заходів, що вживаються фахівцями.

Висновки. Процес переходу спортсменів після завершення професійної кар'єри до життя без спорту є індивідуально забарвленим, складним та тривалим; він залежить від успішності попередньої кар'єри, супроводжується стресовими ситуаціями та негативними емоціями, і часто вимагає раптового завершення для збереження відчуття перемоги.

Ключові слова: спортсмени, адаптація, постспортивне життя, професійна кар'єра, психодіагностика.

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Original scientific article

Programming the Stage of Direct Preparation and Participation in the Main Competitions of the Sports Season for Highly Qualified Field Hockey Players

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Abstract

Background. The modern stage of training highly qualified athletes is characterized by the introduction of technologies into the training process aimed at effective planning and monitoring of training effects. This technology considers programming, which provides an ordered content of the training process, taking into account the main components of training loads.

Objectives. The study purpose was to experimentally determine the effectiveness of building a training process for highly qualified field hockey players at the stage of direct preparation and participation in the main competitions of the sports season based on programming methods.

Materials and methods. A total of 21 highly qualified field hockey players involved in the study. The participants had attained the rank of sports qualification – Master of Sports of Ukraine. The athletes' mean age was 25.6 ± 5.29 years. The study was conducted in 2021 during the preparation and participation of the Ukrainian national field hockey team in the European Championship "Championship 2" (Gniezno, Poland). The scientific search was carried out on the basis of the following methods: theoretical analysis and generalization of scientific and methodical literature; pedagogical observation, pedagogical testing, and methods of mathematical statistics.

Results. The stage structure of direct preparation and participation in the main competitions of the sports season for highly qualified field hockey players was determined. It consisted of three mesocycles: basic – 4-day retractable microcycle, 4-day shock microcycle, 3-day recovery microcycle; special training – 4-day shock microcycle, 3-day recovery microcycle, 4-day preparatory microcycle; competitive – 7-day competitive, 3-day recovery microcycles.

Conclusions. One of the most rational technologies for training athletes is programming, which ensures an ordered content of the training process, taking into consideration the key elements of training loads. Programs of training tasks were developed, which became the basis for micro- and mesocycle programs.

Keywords: field hockey, team game sports, programming method, means of training work, training loads, coordination difficulty modes.

Introduction

The optimal combination of training and competition loads in the competitive period to ensure the maintenance

of the second phase of sports form is one of the debatable issues today (Dubois et al., 2020; Kostiukevych, Lazarenko, Shchepotina et al., 2021; Buy, 2023). In this regard, at the current stage in the system of training athletes, which is based on the theory of periodization of the training process, scientists single out the stage of direct preparation for the main competitions of the sports season (Bompa, Buzzichelli, 2018; Platonov, 2018; Kasper, 2019, etc.). It should ensure the solution of such tasks as recovery, maintaining the achieved

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level of training, creating conditions for the manifestation of the delayed training effect, psychological preparation for the competition, working out the details of preparation according to the model of competitive activity (Platonov, 2018; Shchepotina et al., 2021; Adamchuk et al., 2023). Thus, the problem of developing the structure and content of this stage was defined by many scientists as urgent, in accordance with the demands of the theory and practice of a certain sport (Malikova et al., 2018; Andrade et al., 2021; Leibo et al., 2021).

The analysis of literary sources allowed us to come to the conclusion that the training process of athletes at the stage of direct preparation for the main competitions of the sports season is mainly carried out on the basis of modeling methods (Kostiukevych, 2019; Kostiukevych, Shchepotina, Shynkaruk et al., 2019; Teixeira et al., 2022) and programming (Veličković et al., 2018; Bui, 2022; Bonder, Shim, 2023). It is worth noting that the programming method is used both to improve physical preparedness (Bohuslavska, 2021; Lisenchuk et al., 2023; Hidayah et al., 2024) and technical-tactical (Imas et al., 2018; Pizarro et al., 2019; Perepelitsa, 2021) and integral preparedness (Turliuk, 2017; Kozina et al., 2019; Kostiukevych, Shchepotina, Shynkaruk et al., 2020) of athletes.

Therefore, the analysis of literary sources allows us to state that the scientific search for relatively optimal training of athletes at the stage of preparation for the main competitions of the sports season based on programming methods is relevant for the Olympic sport – field hockey.

Purpose of research – to experimentally determine the effectiveness of building a training process for highly qualified field hockey players at the stage of direct preparation and participation in the main competitions of the sports season based on programming.

Material and Methodology

Participants

21 highly qualified field hockey players participated in the study. Sports qualification – master of sports of Ukraine. The age of the athletes is 25.6 ± 5.29 years. Informed consent was obtained from all players to participate in the study. Research was conducted in accordance with the ethical principles of the Declaration of Helsinki.

Research Organization

The study was conducted in 2021 during the preparation and participation of the Ukrainian national field hockey team in the European Championship “Championship 2” (Gniezno, Poland). National teams took part in the competition: Austria, Iran, Italy, Poland, Switzerland, Scotland, Croatia, Ukraine.

Achieving the goal of the research was carried out on the basis of the following methods: theoretical analysis and generalization of scientific and methodical literature; pedagogical observation, pedagogical testing, methods of mathematical statistics.

The theoretical analysis and generalization of literary sources became the basis for determining the purpose of the research and building a scientific search algorithm for the given problem.

Pedagogical observation was carried out in order to control and analyze the training and competitive activities of the players.

Pedagogical testing made it possible to determine the indicators of physical and functional readiness of players during the stage of direct preparation for the main competitions of the 2021 sports season.

Tests were used to assess speed and speed-strength qualities: a 30 m run from a high start and a long jump from a standing position. General endurance was assessed using the Cooper test (continuous running for 12 min).

Speed endurance was determined on the basis of the test – a shuttle run of 180 m (Fig. 1). Three racks were placed on a straight line at a distance of 15 m from each other. At the coach's signal, the player started running from the first to the second post, ran around it and returned to the first post, then he ran to the third post, ran around it and returned to the first post. After that, the exercise was repeated without stopping.

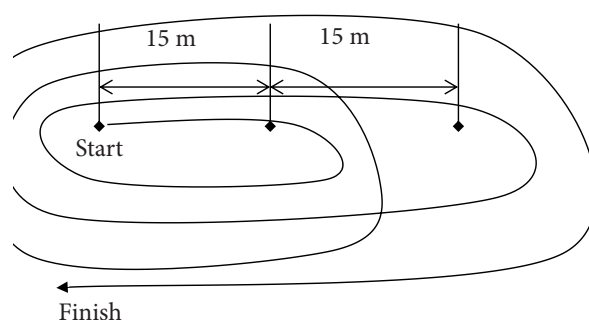


Fig. 1. Scheme of execution of the test “180 m shuttle run”

When performing this test, the following indicators were determined:

- time to cover the distance (s);
- integrative adaptation index (IAI):

$$IAI = t (f_1 + f_2 + f_3), \quad (1)$$

where: t is test execution time;

f_1, f_2, f_3 – heart rate in 10 seconds at the end of the first, second and third minutes of recovery.

Index of operational adaptation (IOA):

$$IOA = \frac{(fw - fr)}{t} \cdot 100, \quad (2)$$

where: fw is heart rate 10 seconds after the end of the test;

fr – heart rate in 10 seconds at the end of the first minute of recovery;

t – duration of test performance.

The functional fitness of the players was assessed based on the indicators of maximum oxygen consumption in absolute terms (VO_{2max} abs, $l \cdot min^{-1}$) and relative (VO_{2max} rel, $ml \cdot min^{-1} \cdot kg^{-1}$) values.

The running version of the test was used to determine these indicators $PWC_{170}(V)$.

Determination of VO_{2max} indicators was carried out according to the following algorithm.

1st step. Without warm-up, ran 800 m in 5 minutes (at a steady pace without acceleration throughout the entire distance).

2nd step. Heart rate fixation immediately after overcoming the first distance (f_i).

3rd step. Determination of running speed when covering the first distance (V_1).

$$V_1 = \frac{S_1}{t_1}, \quad (3)$$

where: S_1 is first distance duration (m);

t_1 – duration of overcoming first distance (s).

4th step. 5 minute rest (stretching).

5th step. 1200 m run in 5 minutes.

6th step. Heart rate fixation immediately after overcoming the second distance (f_2).

7th step. Determination of running speed when covering the second distance (V_2).

$$V_2 = \frac{S_2}{t_2}, \quad (4)$$

where: S_2 – length of the second distance (m);

t_2 – duration of overcoming the second distance (s).

8th step. Determination of physical capacity $PWC_{170(V)}$ using the formula:

$$PWC_{170(V)} = V_1 + (V_2 - V_1) \frac{170 - f_1}{f_2 - f_1} \quad (5)$$

9th step. $PWC_{170(V)}$ ($m \cdot s^{-1}$) value is transferred into PWC_{170} ($kgm \cdot min^{-1}$) using the formula:

$$PWC_{170} = 417 \cdot PWC_{170(V)} - 83 \quad (6)$$

10th step. Determination of absolute value of VO_{2max} .

$$VO_{2max\ abs} = 1,7 \cdot PWC_{170} + 1240 \quad (7)$$

11th step. Determination of relative value of VO_{2max} .

$$VO_{2max\ rel} = \frac{VO_{2max\ abs}}{BM}, \quad (8)$$

where: BM is player's body mass.

The coefficient of the load magnitude is determined by the formula:

$$CLM = \sum_{i=1}^n t_i \cdot I_i, \quad (9)$$

where: CLM is coefficient of load magnitude (points);

t_i – duration of a separate training exercise (minutes);

I_i – the intensity of a separate exercise depending on the heart rate (HR). Heart rate – 114 bpm – 1 point, 120 bpm – 2 points, 126 bpm – 3 points, 132 bpm – 4 points; 138 bpm – 5 points; 144 bpm – 6 points; 150 bpm – 7 points; 156 bpm – 8 points; 162 bpm – 10 points; 168 bpm – 12 points; 174 bpm – 14 points; 180 bpm – 17 points; 186 bpm – 21 points; 192 bpm – 25 points; 198 bpm – 33 points.

In addition to CLM, the coefficient of intensity of training load (CIt.l.) was also determined, which reflected the intensity of the training session:

$$CIt.l. = \frac{CLM}{T}, \quad (10)$$

T – duration of the training session (minutes).

Statistical analysis

Mathematical statistics methods were used to process and analyze the research results. Descriptive statistics using parametric criteria for linked samples were used (Albert et al., 2017; Byshevets et al., 2019; Kostiukevych, Lazarenko, Vozniuk et al., 2020). Determination of the mean value (mean) and the mean square deviation (SD) was assumed. Statistical reliability in the difference between indicators of physical and functional fitness of the studied players was determined using the Student's t-test. Differences were considered significant at $p < 0.050$. Statistical processing of the research results was

carried out on a personal computer using Microsoft Excel XP and Statistica 10.0 application software packages developed by Microsoft and Stat Soft (USA).

Results

The working hypothesis of this study assumed that the content of training classes of highly qualified field hockey players should be determined by clear criteria for planning and control of managerial influences. Programming was chosen as the most optimal scientific and methodical approach to building the players' training process. On the basis of which, step-by-step management influences are carried out, taking into account the appropriate ratio of means of training work and loads of different orientations, taking into account the level of preparation of athletes.

It was determined that the components of the structure of the training process of highly qualified field hockey players at the stage of direct preparation and participation in the main competitions of the sports season (SDP for MC) should be programs of training tasks and various types of microcycles.

The program of the training task is a strictly regulated content of the sportsmen's motor activity, taking into account the types and components of the training work and corresponds to the main purpose and direction of the training process.

The structure of the training task program (TTP) is presented in table 1.

The structure of the training task program (TTP) was determined by:

- the duration of the training task;
- means of training work – general preparatory exercises (GPE), special preparatory exercises (SPE), preparatory (technical and tactical) exercises (PE), competitive exercises (CE);
- load orientation – aerobic (A), mixed (Mx), anaerobic-alactate (AAA), anaerobic-glycolytic (AAG);
- modes of coordination complexity (CMM) of performing exercises: the 1st CCM included exercises performed on the place or at a convenient speed of movement; the 2nd CCM (average coordination difficulty) included exercises performed in motion with limited space and time; the 3rd CCM included exercises performed in conditions of active interference from an opponent (partner) or complex gymnastic and acrobatic exercises;
- coefficient of load magnitude (CLM);
- coefficient of training load intensity (CIt.l.);
- content and scheme of TTP execution;
- TTP execution algorithm;
- components of training work – the duration of a single exercise (t), the intensity of its performance (I), the rest interval between exercises (s), the heart rate during the exercise (HRw), the heart rate at the end of the rest interval (HRR).

This structure of the TTP allows you to clearly define the parameters of training work, both in a separate training session and in a training microcycle (table 2).

Planning of training work in microcycles was carried out on training (competitive) days, taking into account

Table 1. Training task program for improving the speed endurance of highly qualified field hockey players

TTP code		duration of TTP		orientation of TTP				CLM (points)				Clt.l. (points·min ⁻¹)		
TTP: SE (5)		23 min		mainly alactate-glycolytic				232				10.1		
Content and scheme of TTP execution			TTP is aimed at increasing the level of high-speed endurance of players. TTP is held in a stadium with a 400-meter track. TTP is performed in shock microcycles, before performing TTP, a “warm - up” WU: SPT: SPE (3) is performed.											
TTP algorithm (steps)	Content of individual actions (steps) of the TTP	components of training work												
		t	I	CCM	GPE	SPE	PE	CE	Heart rate	CLM (points)	CI _{LI} (points· min ⁻¹)			
1 st	400 m run (V=3.8 m·s ⁻¹)	105”	H	2	-	2’ (Mx)	-	-	168	24	12.0			
2 nd	Walking, stretching	2’	L	1	2’ (A)	-	-	-	120	4	2.0			
3 rd	400 m run (V=4.0 m·s ⁻¹)	100”	H	2	-	2’ (Mx)	-	-	174	28	14.0			
4 th	Walking, stretching	2’	L	1	2’ (A)	-	-	-	120	4	2.0			
5 th	Running 400 m (V=3.8 m·s ⁻¹)	88”	M / Max	2	-	2’ (AAG)	-	-	186	50	25.0			
6 th	Walking, stretching	2’	L	1	2’ (A)	-	-	-	120	6	3.0			
7 th	400 m run (V=3.8 m·s ⁻¹)	88”	M / Max	2	-	2’ (AAG)	-	-	186	50	25.0			
8 th	Walking, stretching	2’	L	1	2’ (A)	-	-	-	126	6	3.0			
9 th	400 m run (V=3.8 m·s ⁻¹)	88”	M / Max	2	-	2’ (AAG)	-	-	186	50	25.0			
10 th	Walking, stretching	2’	L	1	5’ (A)	-	-	-	120	1	2.0			
Total		t	I	CCM	means				loads				CLM	CI _{LI}
					GPE	SPE	PE	CE	A	Mx	AAA	AAG		
		23	L-M/ Max	1 st - 13’ 2 nd - 10’	13	8	-	-	13’	4’	-	6’	232	10.1

Notes: CCM – coordination complexity mode; t – exercise duration; I – exercise intensity: L – low, M – medium, H – high, Max – maximum; GPE – general preparatory exercises; SPE – special preparatory exercises; PE – preparatory exercises; CE – competition exercises; loads: A – aerobic, AAG – anaerobic-glycolytic, Mx – mixed; AAA – anaerobic alactate; CLM – coefficient of load magnitude; Clt.l. – coefficient of intensity of training load

morning and evening classes (games). This structure of the microcycle made it possible to plan and register not only training tools, taking into account CCM and training loads of different directions, but also the amount of training effects at each training session or in the game.

The programs of pull-up, shock, preparatory, competitive and recovery microcycles became the basis for developing the structure and content of the stage of direct training and participation in the main competitions of the sports season of highly qualified field hockey players (fig. 2). This stage consisted of three mesocycles – basic, special-preparatory and competitive. This stage structure made it possible to consistently solve the problems of adapting players to training loads and specific competitive activities.

It is important to note that planning of the magnitude and intensity of training impact in microcycles of the stage was carried out on the basis of the principle of undulation of training loads (fig. 3).

This made it possible to optimally combine the processes of exercise and rest both in microcycles and in general throughout the entire stage of direct preparation and participation of players in the main competitions of the sports season.

The volume and ratio of the means of training work of players at the stage of direct preparation and participation in the main competitions of the sports season is presented

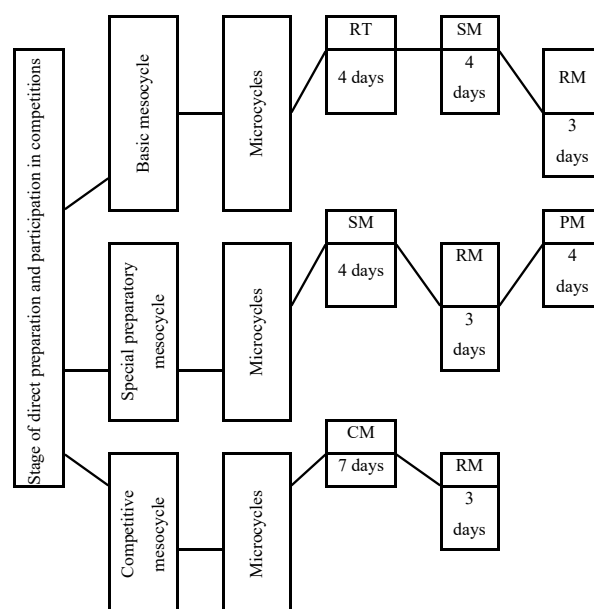


Fig. 2. Structure of the stage of direct training and participation in the main competitions of the sports season of highly qualified field hockey players: Notes: microcycles: RT – retractable; SM – shock; PM – preparatory; CM – competitive; RM – recovery

Table 2. Structure and content of the 4-day lead microcycle for training highly qualified field hockey players

Types and components of training work			Training days															Total						
			1 st			2 nd						3 rd			4 th									
			MT	ET		MT			ET			MT	ET		MT		ET							
				W	TTP	W	TTP	W	TTP	W	TTP		W	TTP	W	TTP								
TTP code				CC (6)	TTM S (2)	GT FVM (1)	TTP (9)	TTM (3)	TP RP (1)	GPE (8)	TP RTS (1)	VSP (1)		CC (6)	SV (2)	TP SP (1)	GPE (8)	TP NP (1)	VSP (1)					
Means, min; CCM	GPE	1	Theoretical class	15	6	6	10	-	8	12	18	10	Recovery measures	15	7	8	12	8	10	Recovery measures	145			
		2		-	-	-	-	-	-	-	-	-		-	-	-	-	-	-		-			
		3		-	-	-	-	-	-	-	-	-		-	-	-	-	-	-		-			
	SPE	1		-	-	-	-	-	-	-	-	-		-	-	-	-	-	-		-	-		
		2		7	-	-	7	-	-	13	-	-		7	10	-	13	-	-		-	57		
		3		-	-	-	-	-	-	-	-	-		-	-	-	-	-	-		-	-		
	PE	1		3	-	-	-	-	-	-	-	-		-	3	-	-	-	-		-	-	6	
		2		4	16	6	7	20	-	6	-	-		4	6	-	6	-	-		-	-	75	
		3		-	-	-	6	10	-	4	-	-		-	-	-	4	-	-		-	-	24	
	CE	1		-	-	-	-	-	-	-	-	20		-	-	-	-	-	-		-	-	-	20
		2		-	-	9	-	-	10	-	-	20		-	-	-	15	-	20		-	-	-	74
		3		-	-	9	-	-	10	-	-	20		-	-	-	15	-	15		-	-	-	69
	A Load, Mx min AAA AAG			15	6	12	12	10	8	23	18	10		15	13	8	23	8	10		191			
				14	-	18	18	20	20	7	60	-		14	-	30	7	35	-		243			
				-	16	-	-	-	-	-	-	-		-	-	-	-	-	-		-	16		
				-	-	-	-	-	-	-	5	-		-	-	10	-	5	-		-	20		
Total, min			29	22	30	30	30	28	35	78	10	29	23	38	35	43	10							
			81			88			123			90			88			470						
CLM, points			170	204	267	190	260	332	266	764	10	170	224	384	266	384	10							
			641			782			1040			660			650			3773						
CI _{tl} , points·min ⁻¹			5.9	9.3	8.9	6.3	8.7	11.9	7.6	9.8	1.0	5.9	9.7	10.1	7.6	8.7	1.0							
			7.9			8.9			8.5			7.3			7.4			8.0						
Load value			M			H			H			M			M			M						
Orientation			A-Mx			Mx			Mx			Mx			Mx			Mx						

Notes: MT – morning training; ET – evening training; W – warm-up; TTP – training task program; CCM – mode of coordination complexity of performing exercises; GPE – general preparatory exercises; SPE – special preparatory exercises; PE – preparatory (technical and tactical) exercises; CE – competitive exercises; loads: a – aerobic; Mx – mixed (aerobic-anaerobic); AAA – anaerobic alactate; AAG – anaerobic glycolytic; CLM – coefficient of the load magnitude; CL_{tl} – coefficient of the training load intensity; Load value: M – medium, H – high

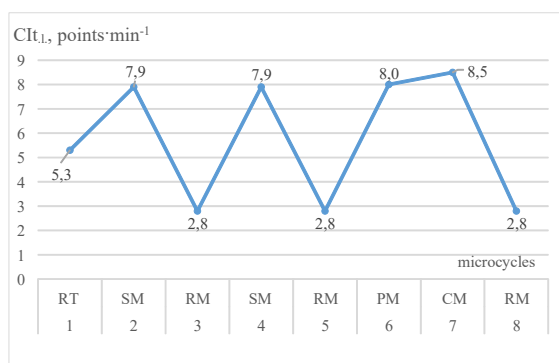


Fig. 3. Dynamics of the intensity of training loads at the stage of direct training and participation in the main competitions of the sports season of highly qualified field hockey players. Notes: microcycles: RT – retractable; SM – shock; RM – recovery; PM – preparatory; CM – competitive

in Table 3. Depending on the type of microcycle in the training process, general preparatory, special preparatory, preparatory and competitive exercises were performed in different proportions.

In the retractable microcycle, only general preparatory exercises were used. Percussion is characterized by the predominant performance of general preparatory (36.0%) and special preparatory (33.8%) exercises. Preparatory and competitive exercises were most often used in preparatory (22.3% and 34.7%) and competitive (17.9% and 41.7%) microcycles.

Training influences on the level of preparedness of players at the stage of direct preparation and participation in the main competitions of the sports season were carried out both through the use of various means and through the application of loads of different orientations (Fig. 4). Training exercises based on aerobic loads were most often used in the 3-day recovery microcycle (85.4%). Mixed (aerobic-anaerobic) loads were mainly used in 4-day shock

Table 3. The volume and ratio of training facilities for highly qualified field hockey players at the stage of direct training and participation in sports season competitions

Microcycles	Training means, min (%)				Total
	General preparatory exercises	Special preparatory exercises	Preparatory exercises	Competitive exercises	
4-day retractable	350 (100)	-	-	-	350
4-day shock	192 (36.0)	180 (33.8)	71 (13.3)	90 (16.9)	533
3-day recovery	156 (75.7)	7 (3.4)	43 (20.9)	-	206
4-day shock	192 (36.0)	180 (33.8)	71 (13.3)	90 (16.9)	533
3-day recovery	156 (75.7)	7 (3.4)	43 (20.9)	-	206
4-day preparatory	145 (30.9)	57 (12.1)	105 (22.3)	163 (34.7)	470
7-day competitive	240 (33.3)	51 (7.1)	129 (17.9)	300 (41.7)	720
3-day recovery	156 (75.7)	7 (3.4)	43 (20.9)	-	206
Total	1587 (49.2)	489 (15.2)	505 (15.7)	643 (19.9)	3224

(36.4 %), 4-day preparatory (51.7 %) and 7-day competitive (56.5 %) microcycles. As for anaerobic loads, when compiling microcycle programs, the greatest use of anaerobic-alactate loads was planned in 4-day shock (14.6 %) and 4-day preparatory (3.4 %) microcycles.

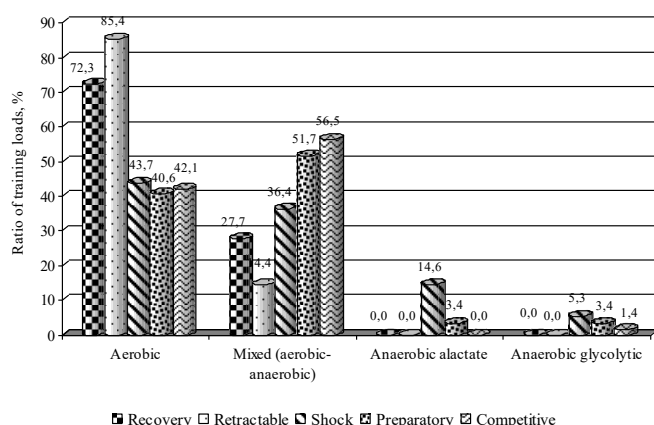


Fig. 4. The ratio (%) of training loads of different directions in microcycles of training highly qualified field hockey players at the stage of direct training and participation in competitions of the sports season

Anaerobic-glycolytic loads were mainly used in 4-day shock (5.3 %) and 4-day preparatory (3.4 %) microcycles. For effective participation of players in competitive activities in field hockey, it is necessary to show a high level of speed and speed-strength qualities, as well as speed and general endurance (table 4).

Comparative analysis of the indicators of physical fitness of players allows us to state that during the SDP for MC of the sports season there were statistically significant changes in the manifestation of speed and strength qualities (1.9 %; $p = 0.032$), speed (3.9 %; $p = 0.013$) and general (2.4 %; $p = 0.027$) endurance. Positive changes in the manifestation of speed qualities were 0.7 % ($p = 0.186$). No less important for the effective competitive activity of highly qualified field hockey players is their level of functional fitness.

To analyse the level of functional readiness of players, the following criteria were selected: $\text{VO}_2\text{max abs}$ ($\text{l}\cdot\text{min}^{-1}$), $\text{VO}_2\text{max rel}$ ($\text{ml}\cdot\text{min}^{-1}\cdot\text{kg}^{-1}$), IAI (integrative adaptation index, rel. units), IOA (index of operational adaptation, rel. units), table 5.

The first two criteria characterize the athletic performance of athletes and the overall level of fitness in accordance with the chosen sport. IAI characterizes the recovery processes of players within a 3-minute rest interval. The IOA indicates that the players' performance is restored during the first minute of rest.

Table 4. Indicators of physical fitness of highly qualified field hockey players at the stage of direct training and participation in competitions of the sports season

Fitness indicators (tests)	At the beginning of SDP for MC			At the end of SDP for MC			Changes		t	p
	n	mean	SD	n	mean	SD	absolute values	%		
Running 30 m from a high start, s	21	4.20	0.14	21	4.17	0.12	0.03	0.7	1.37	0.186
Standing long jump, m	21	2.56	0.19	21	2.61	0.16	0.03	1.9	2.31	0.032
Shuttle run 180 m, s	21	37.68	0.95	21	36.21	0.74	1.47	3.9	2.74	0.013
Cooper's test, m	21	3042.0	126.14	21	3118.1	96.16	76.1	2.4	2.38	0.027

Note: SDP for MC is a stage of direct preparation for the main competitions

Table 5. Indicators of functional readiness of highly qualified field hockey players at the stage of direct training and participation in sports season competitions

Fitness indicators (tests)	At the beginning of SDP for MC			At the end of SDP for MC			Changes		t	p
	n	mean	SD	n	mean	SD	absolute values	%		
VO ₂ max abs, l·min ⁻¹	21	3.89	0.24	21	4.01	0.21	-0.12	2.9	2.16	0.043
VO ₂ max rel, ml·min ⁻¹ ·kg ⁻¹	21	53.1	4.22	21	59.8	4.33	1.7	3.1	2.32	0.031
IAI, rel. units	21	2148.0	114.38	21	2064.4	101.16	83.6	3.8	2.86	0.001
IOA, rel. units	21	20.7	1.18	21	21.4	1.26	0.7	3.3	2.63	0.016

Notes: SDP for MC – stage of direct preparation for the main competitions; VO₂max abs – absolute value of maximum oxygen consumption; VO₂max rel – relative value of maximum oxygen consumption; IAI – integrative adaptation index; IOA – index of operational adaptation

At the end of the SDP for MC of the sports season, the values of the criteria for functional readiness of players increased statistically significantly compared to its beginning. In particular, the values of VO₂max abs increased by 0.12 l·min⁻¹ (2.9 %, $p = 0.043$), VO₂max rel by 1.7 ml·min⁻¹·kg⁻¹ (3.1 %, $p = 0.031$); IAI by 83.6 rel. units (3.8 %, $p = 0.001$), IOA by 0.7 rel. units (3.3 %, $p = 0.016$).

Discussion

The current stage of sports development is determined by the scientific search for the most effective methods of training athletes. This encourages conducting various studies using various technologies for monitoring the training process, building training programs both during long-term improvement and within the framework of annual macrocycles (Leibo et al., 2021; Bui, 2022).

This problem remains relevant for team game sports, including the Olympic sport of field hockey.

The calendar of international competitions of players of the national field hockey team of Ukraine determines participation in the main competitions of the season annually. Usually, these are European Championships, the World League, qualifying tournaments for the Olympic Games. Therefore, the chosen research topic is important both from a scientific point of view for obtaining new knowledge about the parameters of training effects, and from the practical implementation of such a scientific and methodological approach, which is the programming of the training process.

In our study, unlike many authors (Turliiuk, 2017; Platonov, 2018, etc.), we combined the stage of direct preparation for the main competitions of the sports season with the competitions themselves. This allows us to consider the training process of athletes at this stage of the annual training cycle, taking into account the three phases of sports form. Based on this, the structure of the stage of direct training and participation in the main competitions of highly qualified field hockey players in a logical sequence consisted of retractable – shock – recovery – shock – recovery – preparatory – competitive – recovery microcycles.

That is, we can consider such a structure as a corresponding model of the training process of athletes of team game sports when preparing and participating in the main competitions of the sports season.

It is also worth noting that the main basis of programs of structural formations of the training process was developed programs of training tasks, which distinguishes our research from other scientific studies of this problem (Turliiuk, 2017; Imas et al., 2018; Kostiukevych, Shchepotina, Shynkaruk et al., 2019).

The program of each training task is made taking into account all the components of training actions – the duration of the training task, the direction of the load, the ratio of training work tools, the ratio of modes of coordination complexity of performing exercises, coefficients of magnitude and intensity of the training load, and so on.

This approach to the construction of training task programs allows, on the one hand, to program the formation of urgent and delayed training effects, and on the other, to specifically determine the parameters of training work in microcycles and mesocycles of training players at a certain stage of the annual macrocycle.

The lack of statistically significant improvement in 30 m running performance in the studied players is associated with objective difficulties that arise in the process of developing speed abilities in adulthood (Platonov, 2018). At the same time, we observe a positive dynamics of results in this test. In addition, the statistically likely improvement of most indicators of physical and functional fitness of players during the SDP for MC determines the statement about the feasibility of building the training process of highly qualified hockey teams at this stage on the basis of programming, which is also justified in our previous studies (Shchepotina et al., 2021; Adamchuk et al., 2023).

So, the conducted scientific research, which was of an experimental nature, confirmed the predictions regarding the feasibility of using programming in the training process of athletes of team game sports.

Conclusions

The modern stage of training highly qualified athletes is characterized by the introduction of new technologies into the training process, aimed, first of all, at increasing the effectiveness of training effects.

One of the most rational technologies for training athletes is programming, which provides for an ordered content of the training process taking into account the main components of training loads.

It has been experimentally proven that the construction of the training process of highly qualified field hockey players at the stage of direct preparation and participation in the main competitions of the sports season based on programming is effective. The structure of this stage consists of a 4-day retractable, 4-day shock, 3-day recovery, 4-day shock, 3-day recovery, 4-day preparatory, 7-day competition and 3-day recovery microcycles.

It is determined by the ratio of the means of training work and the load of different orientations of the 32-day stage of direct preparation and participation in the main competitions of the sports season of highly qualified field hockey players. Means: 49.2 % – general training, 15.2 % – special training, 15.7 % – preparatory (technical-tactical), 19.9 % – competitive exercises. Training loads: 54.0 % – aerobic; 37.9 % – mixed aerobic-anaerobic, 5.3 % – anaerobic-alactate; 2.8 % – anaerobic-glycolytic.

The prospects of further research will be determined by the scientific search for programming the training macrocycle of highly qualified field hockey players.

Conflict of interests

The authors note that there is no conflict of interests.

References

- Dubois, R., Lyons, M., Paillard, T., Maurelli, O., & Prioux, J. (2020). Influence of weekly workload on physical, biochemical and psychological characteristics in professional rugby union players over a competitive season. *The Journal of Strength & Conditioning Research*, 34(2), 527-545. <https://doi.org/10.1519/JSC.0000000000002741>
- Kostiukevych, V., Lazarenko, N., Shchepotina, N., Vozniuk, T., Shynkaruk, O., Voronova, V., Kutek, T., Konnov, S., Stasiuk, I., Poseletska, K., & Dobrynskiy, V. (2021). Factor Analysis of Special Qualities of Elite Field Hockey Players. *Sport Mont*, 19(S2), 41-47. <https://doi.org/10.26773/smj.210908>
- Buy, I. B. (2023). Dynamics of functional training of biathletes during the macrocycle. *Rehabilitation and Recreation*, (17), 201-206. <https://doi.org/10.32782/2522-1795.2023.17.25>
- Bompa, T.O., & Buzzichelli, C. (2018). *Periodization: theory and methodology of training*. Human kinetics. <https://doi.org/10.5040/9781718225435>
- Platonov, V.N. (2018). The structure and content of the direct preparation of highly qualified athletes for the main competition. *Science in Olympic Sports*, 2, 17-41. https://doi.org/10.32652/olympic2018.2_2
- Kasper, K. (2019). Sports training principles. *Current Sports Medicine Reports*, 18(4), 95-96. <https://doi.org/10.1249/JSR.0000000000000576>
- Shchepotina, N., Kostiukevych, V., Asauliuk, I., Stasiuk, V., Vozniuk, T., Dmytrenko, S., & Adamchuk, V. (2021). Management of training process of team sports athletes during the competition period on the basis of programming (Football-Based). *Physical Education Theory and Methodology*, 21(2), 142-151. <https://doi.org/10.17309/tmfv.2021.2.07>
- Adamchuk, V., Shchepotina, N., Kostiukevych, V., Borysova, O., Bohuslavskaya, V., Tyshchenko, V., Ovcharuk, V., Bondar, A., & Poliak, V. (2023). Optimization of the Training Process of Highly Qualified Athletes in Athletics Combined Events at the Stage of Direct Preparation for Competitions. *Physical Education Theory and Methodology*, 23(2), 236-245. <https://doi.org/10.17309/tmfv.2023.2.12>
- Malikova, A.N., Doroshenko, E.Yu., Symonik, A.V., Tsarenko, E.V., & Veritov, A.I. (2018). The ways of improvement special physical training of high-qualified women volleyball players in competitive period of annual macrocycle. *Physical Education of Students*, 22(1), 38-44. <https://doi.org/10.15561/20755279.2018.0106>
- Andrade, D. M., Fernandes, G., Miranda, R., Coimbra, D. R., & Bara Filho, M. G. (2021). Training load and recovery in volleyball during a competitive season. *The Journal of Strength & Conditioning Research*, 35(4), 1082-1088. <https://doi.org/10.1519/JSC.0000000000002837>
- Leibo, W., Lisenchuk, G., Stasiuk, I., Marzec, A., Zhigadlo, G., Leleka, V., Bogatyrev, K., Derkach, V., Adamenko, O., & Slavitiak, O. (2021). Training Process Structure of Highly Skilled Players in Mini-Football during the Competitive Period. *Sport Mont*, 19(S2), 17-22. <https://www.doi.org/10.26773/smj.210903>
- Kostiukevych, V. (2019) Model indicators of collective interaction of highly qualified football players during the game. *Health, Sports, Rehabilitation*, 5(4), 33-40. <https://doi.org/10.34142/HSR.2019.05.04.04>
- Kostiukevych, V., Shchepotina, N., Shynkaruk, O., Kulchitska, I., Borysova, O., Vozniuk, T., Yakovlii, V., Denysova, L., Konnova, M., Khurtenko, O., Perepelytsia, O., Polishchuk, V., & Shevchyk, L. (2019) Training process construction of the qualified volleyball women players in the preparatory period of two-cycle system of the annual training on the basis of model training tasks. *Journal of Physical Education and Sport*, 19(2), 427-435. <https://doi.org/10.7752/jpes.2019.S2063>
- Teixeira, J.E., Branquinho, L., Leal, M., Marinho, D.A., Ferraz, R., Barbosa, T.M., Monteiro, A.M., & Forte, P. (2022). Modeling the Major Influencing Factor on Match Running Performance during the In-Season Phase in a Portuguese Professional Football Team. *Sports*, 10(8), 121. <https://doi.org/10.3390/sports10080121>
- Veličković, M., Bojić, I., & Berić, D. (2018). The Effects Of Programmed Training On Development Of Explosive Strength In Female Volleyball Players. *Facta Universitatis, Series: Physical Education and Sport*, 15(3), 493-499. <https://doi.org/10.22190/FUPES1703493V>
- Bui, I. (2022). Technology of programming the training process of qualified biathletes in the macrocycle. *Physical culture sports and health of the nation*, 13(32), 366-371. [https://doi.org/10.31652/2071-5285-2022-13\(32\)-366-371](https://doi.org/10.31652/2071-5285-2022-13(32)-366-371)
- Bonder, I. J., & Shim, A. L. (2023). In-Season training model for national association of intercollegiate athletics female basketball players using “Microdosed” programming. *Strength & Conditioning Journal*, 45(4), 395-410. <https://doi.org/10.1519/SSC.0000000000000741>
- Bohuslavskaya, V.Yu. (2021). Structure and content of programs of training classes aimed at improving the physical fitness of rowers. *Theoretical and methodological aspects of programming and modeling of the training process of*

- athletes of various qualifications: a collective monograph. Vinnytsia: Tvory, 17-34.
- Lisenchuk, G., Leleka, V., Bogatyrev, K., Kokareva, S., Adamenko, O., Shchekotylna, N., Romanenko, S., & Krupenya, S. (2023). Fitness training in functional preparedness of highly qualified football players. *Journal of Physical Education and Sport*, 23(2), 502-509. <https://doi.org/10.7752/jpes.2023.02062>
- Hidayah, T., Akhiruyanto, A., Haryono, S., & Yudhistira, D. (2024). The Linear and nonlinear programming: effects on the physical abilities of young basketball players. *Pedagogy of Physical Culture and Sports*, 28(4), 274-282. <https://doi.org/10.15561/26649837.2024.0404>
- Imas, Y., Borysova, O., Dutchak, M., Shlonska, O., Kogut, I., & Marynych, V. (2018). Technical and tactical preparation of elite athletes in team sports (volleyball). *Journal of Physical Education and Sport*, 18(2), 972-979. <https://doi.org/10.7752/jpes.2018.02144>
- Pizarro, D., Práxedes, A., Travassos, B., del Villar, F., & Moreno, A. (2019). The effects of a nonlinear pedagogy training program in the technical-tactical behaviour of youth futsal players. *International Journal of Sports Science & Coaching*, 14(1), 15-23. <https://doi.org/10.1177/1747954118812072>
- Perepelytsia, M. (2021). Programming of tactical training of highly qualified field hockey players in the annual macro cycle. *Physical culture, sport and health of the nation*, 11(30), 210-219. [https://doi.org/10.31652/2071-5285-2021-11\(30\)-210-219](https://doi.org/10.31652/2071-5285-2021-11(30)-210-219)
- Turliuk, V. (2017). Analysis of structure and content of studying and training process of hurdles during the preparing process of year cycle. *Journal of Education, Health and Sport*, 7(1), 808-823.
- Kozina, Z., Cretu, M., Safronov, D., Gryn, I., Shkrebtii, Y., Bugayets, N., Shepelenko, T., & Tanko, A. (2019). Dynamics of psychophysiological functions and indicators of physical and technical readiness in young football players aged 12-13 and 15-16 years during a 3-month training process. *Physiotherapy Quarterly*, 27(3), 20-27. <https://doi.org/10.5114/pq.2019.86464>
- Kostiukevych, V., Shchepotina, N., Shynkaruk, O., Koliadych, Y., Hatsoieva, L., Voronova, V., Vozniuk, T., Kaplinskyi, V., Diachenko, A., Chernyshenko, T., & Konnova, M. (2020). Highly qualified grass hockey sportswomen's adaptation to training intensity in the macrocycle preparatory period. *Journal of Physical Education and Sport*, 20(S1), 385-394. <https://doi.org/10.7752/jpes.2020.s1055>
- Albert, J., Glickman, M. E., Swartz, T. B., & Koning, R. H. (Eds.). (2017). *Handbook of statistical methods and analyses in sports*. CRC Press.
- Byshevs, N., Denysova, L., Shynkaruk, O., Serhiyenko, K., Usychenko, V., Stepanenko, O., & Syvash, I. (2019). Using the methods of mathematical statistics in sports and educational research. *Journal of Physical Education and Sport*, 19(3), 1030-1034. <https://doi.org/10.7752/jpes.2019.s3148>
- Kostiukevych, V., Lazarenko, N., Vozniuk, T., Shchepotina, N., Shynkaruk, O., Valentina, V., Borysova, O., Didyk, T., Perepelytsia, O., Hudyma, S., & Bezmylov, N. (2020). Choice and experimental substantiation of tests for controlling physical and technical preparedness of hockey players. *Journal of Physical Education and Sport*, 20(5), 2735-2744. <https://doi.org/10.7752/jpes.2020.05372>

Програмування етапу безпосередньої підготовки та участі в головних змаганнях спортивного сезону висококваліфікованих хокеїстів на траві

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

Реферат. Стаття: 10 с., 5 табл., 4 рис., 29 джерел.

Історія питання. Сучасний етап підготовки спортсменів високої кваліфікації характеризується впровадженням у тренувальний процес технологій, спрямованих на ефективне планування та контроль тренувальних впливів. Такою технологією розглядається програмування, що передбачає упорядкований зміст тренувального процесу з урахуванням основних компонентів тренувальних навантажень.

Мета дослідження. Експериментально визначити ефективність побудови тренувального процесу висококваліфікованих хокеїстів на траві на етапі безпосередньої підготовки та участі в головних змаганнях спортивного сезону на основі методів програмування.

Матеріал і методи. У дослідженні брали участь 21 висококваліфікований хокеїст на траві. Спортивна кваліфікація – майстер спорту України. Вік спортсменів 25,6 ± 5,29 років. Дослідження проводилося у 2021 році в період підготовки та

участі національної збірної команди України з хокею на траві до чемпіонату Європи «Чемпіоншип 2» (м. Гнезно, Польща). Науковий пошук здійснювався на основі таких методів: теоретичний аналіз та узагальнення науково-методичної літератури; педагогічне спостереження, педагогічне тестування, методи математичної статистики.

Результати дослідження. Визначено структуру етапу безпосередньої підготовки та участі в головних змаганнях спортивного сезону висококваліфікованих хокеїстів на траві, що складалася з трьох мезоциклів: базового – 4-денний утягувальний, 4-денний ударний, 3-денний відновлювальний мікроцикли; спеціально-підготовчого – 4-денний ударний, 3-денний відновлювальний, 4-денний підвідний мікроцикли; змагального – 7-денний змагальний, 3-денний відновлювальний мікроцикли.

Висновки. Однією з найбільш раціональних технологій підготовки спортсменів є програмування, що забезпечує впорядкований зміст тренувального процесу з урахуванням ключових елементів тренувальних навантажень. Були розроблені програми тренувальних завдань, які стали основою для мікро- і мезоциклічних програм..

Ключові слова: хокей на траві, командні ігрові види спорту, метод програмування, засоби тренувальної роботи, тренувальні навантаження, режими координаційної складності.

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Comparative Analysis of Balance Metrics in Injured versus Healthy Professional Tennis Players

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Abstract

Objectives. Knee injuries are prevalent among professional tennis players and have a significant impact on their athletic performance and longevity. This study aimed to evaluate the dynamic and postural balance differences between injured and healthy professional tennis players, reflecting the broader implications of knee injuries on player stability and performance.

Materials and methods. A total of 80 professional tennis players, comprising 40 individuals in the knee injury group (IG) and 40 individuals in the non-injury group (NIG), were selected to participate in this cross-sectional study. Participants' postural sway was assessed under various conditions, including standing on different surfaces with open and closed eyes using a Wii Balance Board. The Y-Balance Test was performed to evaluate the player's dynamic balance. An Independent t-test was used to examine the difference in postural sway and dynamic balance between the two groups.

Results. The results of this study indicated that players with knee injuries showed significantly worse performance in both dynamic balance ($p < 0.05$ for non-dominant legs) and postural sway (significant differences in mean velocity on foam surfaces with eyes open and closed, $p < 0.001$). These findings suggest that knee injuries contribute to substantial deficits in balance control, which could affect overall athletic performance and injury risk.

Conclusion. The study underscores the necessity of incorporating targeted balance and proprioceptive training into rehabilitation programs for tennis players recovering from knee injuries. By improving balance, these interventions can enhance neuromuscular control, reduce reinjury risk, and support better overall performance in high-stakes environments. Future research should focus on refining balance training programs to maximize recovery outcomes and minimize injury impacts.

Keywords: tennis players, balance, knee injury, health risk, postural sway.

Introduction

Tennis is classified as an intermittent sport, distinguished by repeating high-intensity challenges, such as accelerations and decelerations, throughout competitive matches that

typically last 90 minutes (Fernandez-Fernandez et al., 2018). The musculoskeletal system of the lower limbs can experience significant stress due to the repetitive lateral, start/stop, and turning movements performed by tennis players. These movements involve fast anterior or posterior transitions, followed by forceful strokes (Manske & Paterno, 2018). Racquet sports may also encompass abrupt, lateral motions, resulting in substantial valgus and rotatory forces on the knee joint (Prieske et al., 2014). Due to the execution of this faster agility movement, lower limb injuries are

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prevalent among tennis players due to the recurrent loadings experienced during matches, which may last up to five hours (Okholm Kryger et al., 2015).

29% of tennis injuries are attributed to knee injuries (O'Connor et al., 2020). Research has demonstrated that the knee is the most frequently injured area among male professional players and the third most frequently injured area among female professional players during the 2011-2016 Australian Open Grand Slam (Gescheit et al., 2017). The most prevalent injuries among junior tennis players include ankle sprains, lower back pain, and knee problems (Gescheit et al., 2019). In terms of gender, it was observed that female players exhibited a higher prevalence of Anterior cruciate ligament (ACL) injuries than their male counterparts (Kaiser et al., 2021). Previous studies have demonstrated a potential association between ACL injury and an increased likelihood of knee reinjury, resulting in prolonged disability and a greater risk of early onset of osteoarthritis (de Sire et al., 2021). Individuals who had previously experienced a knee injury within the joint showed imbalances in their ability to maintain stability for up to 3-10 years after the injury. This was characterized by a more consistent centre of pressure (COP) and an increase in the extent of movement during periods of quiet standing on one leg (Baltich et al., 2015).

Tennis involves swift and multidirectional movements, such as sudden decelerations and pivoting (Fernandez-Fernandez et al., 2018). These physical and technical needs necessitate sufficient balance levels, which are crucial in achieving success in tennis (Malliou et al., 2010a). Dynamic balance, an essential component in the sport of tennis, pertains to the intrinsic tendency of the human body to spontaneously adjust its body position to sustain a state of relative stability during movement or when exposed to external stimuli (Novak et al., 2023). Such balance enhances drill performance and reduces the likelihood of sustaining injuries in the lower extremities (Caballero et al., 2021). In this context, previous studies compared the dynamic balance and postural balance between novice and professional tennis players in various conditions, such as eyes open (EO) and eyes closed (EC) (Srihi et al., 2022). Another study was conducted to evaluate the balanced performance of young tennis players before and after training sessions (Malliou et al., 2010b). Subsequently, prior research has also included comparisons of postural control across several athletic groups, including volleyball, basketball, and gymnastics (Galli et al., 2017). Prior research has also investigated the correlation between balance and performance among tennis players across various age groups and skill levels (Caballero et al., 2021) and the effect of leg preference and dominance on postural balance among tennis players (Kozinc & Šarabon, 2021). Nevertheless, there needs to be more data about the impact of knee injuries on balance and postural control in professional tennis players. Hence, this study compares the dynamic balance and postural sway among professional tennis players with and without knee injury.

Materials and Methods

Study Design

A cross-sectional observational study compared dynamic balance and postural sway in professional tennis players with and without knee injuries.

Sampling Size

A pilot study estimated the sample size required to compare dynamic balance and postural sway between professional tennis players with and without knee injuries. First, the investigators recruited a small sample of participants ($n = 10$) in each group. Second, both dynamic balance and postural sway were measured and recorded. Third, the mean and standard deviation were measured for each variable within each group. Further, these statistics were used to estimate the pooled standard deviation and the effect size (difference in means divided by the pooled standard deviation). Finally, using G*Power software, these estimates will be used in a sample size formula to determine the sample size for the main study. Considering these parameters, the authors aimed to have 40 samples in each group.

Participants

80 male professional tennis players aged between 18 and 35 who participated in at least two national and state-level competitions were recruited for this cross-sectional study. The subjects were divided into an injured group (IG = 40) and a non-injured group (NIG = 40). The participants in the IG had a history of sports-related intra-articular knee injuries, which included grade 1 ligament and meniscus injury, three months ago, which kept them away from participating in the game. The subjects were excluded if they had any history of surgery or fractures in the lower limb, vestibular disorders, or other neurological impairments. Basic demographic data like playing experience, frequency of training, and training duration of the subjects were collected.

Ethical Approval:

The University Research and Ethical Committee approved all study procedures under the reference number INTI-IU/FHLS-RC/BPHTI/1NY12023/021. To obtain their informed consent, participants were fully informed about the study's objectives, potential risks, and benefits. They were also reminded that they could withdraw from the study anytime.

Outcome Measure

Dynamic Balance

The Y-Balance test (YBT) equipment (FMSTM, USA) was utilized to conduct a dynamic balance test. It is a reliable test to assess the dynamic neuromuscular test (Plisky et al., 2021). To do the test, individuals must position their hands on the hips and extend their reach by exerting force on the board using the reaching limb in the anterior, posteromedial, and posterolateral directions. Subsequently, they should return to the initial starting position. The measurement of reach distance was conducted within a range of 0.5 cm from the nearest edge of the reach indicator. The test was performed for both dominant and non-dominant lower extremities. Before the actual test trials, all individuals engaged in three practice trials on each leg in each of the three orientations. The reach distances of the YBT were converted to leg length (%) by measuring the length from the participants' right anterior

superior iliac spine to the right medial malleolus while lying down. The greatest composite score was determined using the following formula:

Composite score = $[(\text{sum of the 3 distances})/(\text{length of lower limb} \times 3)] \times 100$

Postural Sway

The Wii Balance Board (WBB) is a widely accessible, cost-effective technology for measuring standing body sway kinematics (Rohof et al., 2020). The WBB (Sensing Future Technologies, Coimbra, Portugal) was connected to a laptop computer running a customized Microsoft Windows 11 operating system to establish a Bluetooth connection and connect to the WBB. The data from the force platform were sampled at 100 Hz. It has two dual-channel analog-to-digital converters (ADCs) to sample the four load cells in each platform corner. Postural sway was analyzed through Physiosensing Balance Software® v.21.5.0.0. Sensing Future, Coimbra, Portugal. The participants were directed to maintain an upright position on the WBB, with their heels spaced 2 cm apart, a stance angle of 30 degrees, and their arms hanging loosely at the sides of their bodies. We evaluated the individuals' postural stability in two different conditions on a firm and foam surface: a) with their eyes open (EO) and their gaze directed towards a black circle at a distance of 2 meters for 60 seconds; b) with their eyes closed (EC), for the same duration (Andreeva et al., 2021). Ellipse Area (mm²), Mean of the Centre of Pressure (COP) trajectory in anteroposterior and mediolateral direction (mm), and Mean Velocity of COP (mm/s) parameters were recorded.

Results

Table 1 summarizes demographic data such as Age, Body mass index (BMI), Playing experience, frequency of training, and training duration.

Table 1. Demographic Data of the participants from both study groups

Indexes	Injured (n = 40)	Non-injured (n = 40)
	Mean ± SD	Mean ± SD
Age	24.40 ± 4.99	22.85 ± 5.46
BMI	22.36 ± 3.05	22.17 ± 2.21
Playing experience	17.25 ± 6.48	14.90 ± 8.94
Training days/week	3.80 ± 0.88	4.00 ± 1.06
Training hours	2.35 ± 0.66	2.60 ± 0.81

Body mass index (BMI), SD-Standard deviation

Discussion

The findings of this study reveal significant differences in dynamic and postural balance between professional tennis players with knee injuries and their healthy counterparts. These results align with existing literature that underscores the critical role of balance in athletic performance and injury prevention.

Professional tennis players are exposed to repetitive high-intensity movements, including rapid accelerations,

Table 2. Mean and standard deviation between the group on a firm surface with eyes open and closed.

Indexes	Group	Mean $\pm$ SD	df	t	p
Eyes Open					
EA	Injured Group	476.52 $\pm$ 229.53	78	1.788	0.78
	Non-Injured Group	391.76 $\pm$ 192.95			
AP	Injured Group	20.79 $\pm$ 13.55	78	2.513	0.014
	Non-Injured Group	13.90 $\pm$ 10.78			
ML	Injured Group	3.91 $\pm$ 11.45	78	0.144	0.886
	Non-Injured Group	4.33 $\pm$ 14.33			
MV	Injured Group	19.67 $\pm$ 7.70	78	6.057	0.001*
	Non-Injured Group	11.03 $\pm$ 4.69			
Eyes Closed					
EA	Injured Group	482.56 $\pm$ 263.22	78	0.395	0.694
	Non-Injured Group	453.54 $\pm$ 383.14			
AP	Injured Group	17.74 $\pm$ 15.91	78	1.283	0.203
	Non-Injured Group	13.79 $\pm$ 11.26			
ML	Injured Group	2.27 $\pm$ 14.97	78	0.072	0.943
	Non-Injured Group	2.52 $\pm$ 15.70			
MV	Injured Group	23.75 $\pm$ 12.21	78	5.492	0.001*
	Non Injured Group	12.50 $\pm$ 4.29			

*EA = Ellipse Area (mm²); AP = Mean COPap displacement (AP) (mm); ML = Mean COPml displacement (ML)(mm); MV = Mean Velocity (mm/s); *p < 0.05

Table 3. Mean and standard deviation between the groups on foam surfaces with eyes open and closed

Indexes	Group	Mean ± SD	df	t	p
Eyes Open					
EA	Injured Group	563.24 ± 266.54	78	1.815	0.073
	Non-Injured Group	468.27 ± 196.16			
AP	Injured Group	16.40 ± 13.85	78	0.484	0.630
	Non-Injured Group	17.76 ± 11.07			
ML	Injured Group	0.62 ± 13.23	78	0.429	0.669
	Non-Injured Group	1.75 ± 10.04			
MV	Injured Group	18.33 ± 7.121	78	4.091	0.001*
	Non-Injured Group	13.20 ± 3.49			
Eyes Closed					
EA	Injured Group	737.07 ± 368.06	78	0.630	0.531
	Non-Injured Group	810.76 ± 641.80			
AP	Injured Group	18.92 ± 8.13	78	0.413	0.681
	Non-Injured Group	8.00 ± 11.52			
ML	Injured Group	1.75 ± 16.90	78	0.501	0.618
	Non-Injured Group	3.48 ± 13.79			
MV	Injured Group	21.10 ± 7.93	78	1.379	0.172
	Non-Injured Group	18.03 ± 11.60			

*EA = Ellipse Area (mm²); AP = Mean COPap displacement (AP) (mm); ML = Mean COPml displacement (ML)(mm); MV: Mean Velocity (mm/s); *p < 0.05

Table 4. Y-Balance Test composite scores of Dominant Leg and Non-Dominant Leg between injured and non-injured groups

Dynamic Balance	Injured (N = 40)	Non-Injured (N = 40)	df	t	p
	Mean ± SD	Mean ± SD			
DL	98.98 ± 11.66	104.14 ± 9.41	78	2.17	0.032*
NDL	101.66 ± 11.16	104.79 ± 11.68	78	1.234	0.021*

*DL = Dominant Leg; NDL = Non-Dominant Leg, *p < 0.05

decelerations, and multidirectional changes, which place considerable stress on their lower limbs, particularly the knee joint (Fernandez-Fernandez et al., 2018; Manske & Paterno, 2018). These stresses significantly contribute to the high incidence of knee injuries observed among these athletes, as seen in previous studies that report knee injuries as one of the most common injuries in tennis (O'Connor et al., 2020; Okholm Kryger et al., 2015). These high-intensity movements can lead to dynamic knee valgus, a modifiable injury risk factor (Wilczyński et al., 2021).

The significant differences in dynamic balance observed between the injured and non-injured groups suggest that knee injuries can substantially impair an athlete's ability to maintain stability during movement. Dynamic balance, crucial for performance in sports involving rapid and unpredictable movements, such as tennis, is significantly affected by knee injuries (Caballero et al., 2021; Novak et al., 2023). The Y-Balance Test (YBT) results from this study corroborate findings from other research indicating that lower limb injuries negatively impact dynamic balance, highlighting the need for targeted rehabilitation protocols (Huang et al., 2023; Plisky et al., 2021).

Furthermore, the impaired postural sway in injured players, as evidenced by significant differences in COP mean displacement and velocity on both firm and foam surfaces, reflects the long-term impact of knee injuries on postural control. Previous research has demonstrated that individuals with knee injuries exhibit persistent balance impairments, which can extend several years post-injury, affecting their overall postural stability and increasing the risk of reinjury (Baltich et al., 2015; Harry-Leite et al., 2022). Proprioceptive exercises have been shown to improve knee position sense and balance, suggesting their potential inclusion in rehabilitation programs (Harry-Leite et al., 2022).

The study's findings emphasize the importance of incorporating balance training into rehabilitation programs for injured tennis players. Balance training has been shown to improve neuromuscular control and reduce the likelihood of further injuries, enhancing overall athletic performance (Malliou et al., 2010b; Prieske et al., 2014). Rehabilitation strategies focusing on dynamic and static balance can help mitigate the effects of knee injuries and support recovery (Caballero et al., 2021; Galli et al., 2017).

Fatigue also plays a critical role in athletes' dynamic balance. Studies have shown that fatigue can significantly decrease the range of motion and joint torque, reducing balance and increasing the risk of injuries (Huang et al., 2023). This highlights the need for balance training programs that also consider the effects of fatigue on performance and injury prevention.

Limitations

This study is subject to several limitations that must be acknowledged. First, the exclusive focus on male participants limits the generalizability of the findings to female athletes, who may exhibit different biomechanical responses and rehabilitation needs. Additionally, the study's cross-sectional nature restricts our ability to infer causal relationships between knee injuries and balance impairments. Moreover, focusing solely on knee injuries may overlook the impact of other common injuries in tennis on balance metrics. Lastly, the lack of control over environmental variables such as playing surface and testing conditions could influence the outcomes, limiting the study's external validity. Once published, these findings will be added to the existing content at the end of this article.

Recommendations

Future research should address the limitations noted in this study to enhance the applicability and relevance of the findings. Including male and female athletes in the study would help broaden the understanding of gender-specific responses to knee injuries and rehabilitation. Employing a longitudinal design would allow for observing changes over time and establishing causal links between knee injuries and balance outcomes. Expanding the focus beyond knee injuries to include other common injuries could provide a more comprehensive insight into the balance needs of tennis players. Utilizing more advanced biomechanical testing that closely mimics actual tennis play would likely yield results more applicable to real-world scenarios. Furthermore, standardizing environmental and testing conditions across studies would help ensure the consistency and reliability of the results, making them more helpful in developing targeted interventions and rehabilitation programs. These suggestions will be considered for inclusion in future updates to this article.

Conclusion

In conclusion, the significant differences in dynamic and postural balance between injured and healthy professional tennis players highlight the critical impact of knee injuries on these athletes. Integrating comprehensive balance training into rehabilitation protocols is essential for improving postural control, reducing reinjury risk, and optimizing performance. Future research should explore the components of effective balance training programs and their long-term benefits for injured athletes.

Conflict of interests

The authors declare that they have no conflicts of interest.

Reference

- Fernandez-Fernandez, J., Granacher, U., Sanz-Rivas, D., Marín, J. M. S., Hernandez-Davo, J. L., & Moya, M. (2018). Sequencing effects of neuromuscular training on physical fitness in youth elite tennis players. *The Journal of Strength & Conditioning Research*, 32(3), 849-856. <https://doi.org/10.1519/jsc.0000000000002319>

- Manske, R. C., & Paterno, M. V. (2018). Rehabilitation of knee injuries. *Tennis Medicine: A Complete Guide to Evaluation, Treatment, and Rehabilitation*, 415-437. https://doi.org/10.1007/978-3-319-71498-1_27
- Prieske, O., Mühlbauer, T., Krueger, T., Kibele, A., Behm, D., & Granacher, U. (2014). Sex-specific effects of surface instability on drop jump and landing biomechanics. *International Journal of Sports Medicine*, 75-81. <https://doi.org/10.1055/s-0034-1384549>
- Okholm Kryger, K., Dor, F., Guillaume, M., Haida, A., Noirez, P., Montalvan, B., & Toussaint, J.-F. (2015). Medical reasons behind player departures from male and female professional tennis competitions. *The American Journal of Sports Medicine*, 43(1), 34-40. <https://doi.org/10.1177/0363546514552996>
- O'Connor, S., Huseyin, O. R., Whyte, E. F., & Lacey, P. (2020). A 2-year prospective study of injuries and illness in an elite national junior tennis program. *The Physician and Sportsmedicine*, 48(3), 342-348. <https://doi.org/10.1080/00913847.2020.1714512>
- Gescheit, D. T., Cormack, S. J., Duffield, R., Kovalchik, S., Wood, T. O., Omizzolo, M., & Reid, M. (2017). Injury epidemiology of tennis players at the 2011–2016 Australian Open Grand Slam. *British Journal of Sports Medicine*, 51(17), 1289-1294. <https://doi.org/10.1136/bjsports-2016-097283>
- Gescheit, D. T., Cormack, S. J., Duffield, R., Kovalchik, S., Wood, T. O., Omizzolo, M., & Reid, M. (2019). A multi-year injury epidemiology analysis of an elite national junior tennis program. *Journal of Science and Medicine in Sport*, 22(1), 11-15. <https://doi.org/10.1016/j.jsams.2018.06.006>
- Kaiser, P., Stock, K., Benedikt, S., Ellenbecker, T., Kastenberger, T., Schmidle, G., & Arora, R. (2021). Acute tennis injuries in the recreational tennis player. *Orthopaedic Journal of Sports Medicine*, 9(1), 2325967120973672. <https://doi.org/10.1177/2325967120973672>
- de Sire, A., Marotta, N., Demeco, A., Moggio, L., Paola, P., Marotta, M., Iona, T., Invernizzi, M., Leigheb, M., & Ammendolia, A. (2021). Electromyographic assessment of anterior cruciate ligament injury risk in male tennis players: Which role for visual input? a proof-of-concept study. *Diagnostics*, 11(6), 997. <https://doi.org/10.3390/diagnostics11060997>
- Baltich, J., Whittaker, J., Von Tschanner, V., Nettel-Aguirre, A., Nigg, B. M., & Emery, C. (2015). The impact of previous knee injury on force plate and field-based measures of balance. *Clinical Biomechanics*, 30(8), 832-838. <https://doi.org/10.1016/j.clinbiomech.2015.06.005>
- Malliou, V. J., Beneka, A. G., Gioftsidos, A. F., Malliou, P. K., Kallistratos, E., Pafis, G. K., Katsikas, C. A., & Douvis, S. (2010a). Young tennis players and balance performance. *The Journal of Strength & Conditioning Research*, 24(2), 389-393. <https://doi.org/10.1519/jsc.0b013e3181c068f0>
- Novak, D., Sinković, F., Bilić, Z., & Barbaros, P. (2023). The Effects of a Short Virtual Reality Training Program on Dynamic Balance in Tennis Players. *Journal of Functional Morphology and Kinesiology*, 8(4), 168. <https://doi.org/10.3390/jfmk8040168>
- Caballero, C., Barbado, D., Hernández-Davó, H., Hernández-Davó, J. L., & Moreno, F. J. (2021). Balance dynamics are related to age and levels of expertise. Application in young and adult tennis players. *PloS One*, 16(4), e0249941. <https://doi.org/10.1371/journal.pone.0249941>
- Malliou, V. J., Beneka, A. G., Gioftsidos, A. F., Malliou, P. K., Kallistratos, E., Pafis, G. K., Katsikas, C. A., & Douvis, S. (2010b). Young tennis players and balance performance. *The Journal of Strength & Conditioning Research*, 24(2), 389-393. <https://doi.org/10.1519/jsc.0b013e3181c068f0>
- Srihi, S., Jouira, G., Ben Waer, F., Rebai, H., Majdoub, A., & Sahli, S. (2022). Postural Balance in Young Tennis Players of Varied Competition Levels. *Perceptual and Motor Skills*, 129(5), 1599-1613. <https://doi.org/10.1177/00315125221108913>
- Galli, M., Cimolin, V., Rigoldi, C., Moro, M., Loi, A., & Pau, M. (2017). Postural sway in adolescent athletes: a comparison among volleyball, basketball and gymnastics players. *Gazzetta Medica Italiana. Archivio Per Le Scienze Mediche*, 176(10), 515-520. <https://doi.org/10.23736/s0393-3660.17.03411-8>
- Kozinc, Ž., & Šarabon, N. (2021). The effects of leg preference and leg dominance on static and dynamic balance performance in highly-trained tennis players. *Plos One*, 16(11), e0259854. <https://doi.org/10.1371/journal.pone.0259854>
- Andreeva, A., Melnikov, A., Skvortsov, D., Akhmerova, K., Vavaev, A., Golov, A., Draugelite, V., Nikolaev, R., Chechelnickaia, S., & Zhuk, D. (2021). Postural stability in athletes: The role of sport direction. *Gait & Posture*, 89, 120-125. <https://doi.org/10.1016/j.gaitpost.2021.07.005>
- Rohof, B., Betsch, M., Rath, B., Tingart, M., & Quack, V. (2020). The Nintendo® Wii Fit Balance Board can be used as a portable and low-cost posturography system with good agreement compared to established systems. *European Journal of Medical Research*, 25, 1-8. <https://doi.org/10.1186/s40001-020-00445-y>
- Harry-Leite, P., Paquete, M., Teixeira, J., Santos, M., Sousa, J., Fraiz-Brea, J. A., & Ribeiro, F. (2022). Acute impact of proprioceptive exercise on proprioception and balance in athletes. *Applied Sciences*, 12(2), 830. <https://doi.org/10.3390/app12020830>
- Huang, C., Ye, J., Song, Y., Kovács, B., Baker, J. S., Mao, Z., & Gu, Y. (2023). The Effects of Fatigue on the Lower Limb Biomechanics of Amateur Athletes during a Y-Balance Test. *Healthcare*, 11(18), 2565. <https://doi.org/10.3390/healthcare11182565>
- Plisky, P., Schwartkopf-Phifer, K., Huebner, B., Garner, M. B., & Bullock, G. (2021). Systematic review and meta-analysis of the Y-balance test lower quarter: reliability, discriminant validity, and predictive validity. *International Journal of Sports Physical Therapy*, 16(5), 1190. <https://doi.org/10.26603/001c.27634>
- Wilczyński, B., Wąż, P., & Zorena, K. (2021). Impact of three strengthening exercises on dynamic knee valgus and balance with poor knee control among young football players: A randomized controlled trial. *Healthcare*, 9(5), 558. <https://doi.org/10.3390/healthcare9050558>

Порівняльний аналіз показників рівноваги у травмованих та здорових професійних тенісистів

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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. Травми колінного суглоба є поширеною проблемою серед професійних тенісистів і мають значний вплив на рівень їхньої спортивної результативності та тривалості спортивної кар'єри. Метою цього дослідження була оцінка відмінностей у динамічній та постуральній рівновазі між травмованими та здоровими професійними тенісистами, що відображає більш широкі наслідки травм колінного суглоба на показники стабільності та результативності гравців.

Матеріали та методи. Загалом до участі в цьому поперечному дослідженні було відібрано 80 професійних тенісистів, з яких 40 осіб входили до групи з травмою колінного суглоба (ТГ) і 40 осіб – до групи з відсутністю травми (ВТГ). За допомогою балансувальної дошки Wii Balance Board оцінювали постуральне коливання учасників за різних умов, включаючи положення стоячи на різних поверхнях з розплющеними та заплющеними очима. З метою оцінки динамічної рівноваги гравця проводився баланс-тест (Y-Balance Test). Для перевірки різниці в постуральних коливаннях і динамічній рівновазі між двома групами учасників був застосований t-критерій для незалежних вибірок.

Результати. Результати дослідження свідчать про суттєво гірші показники гравців з травмами колінного суглоба як у динамічній рівновазі ($p < 0,05$ для недомінантних ніг), так і в постуральному коливанні (достовірні відмінності у середній швидкості на пінопластових поверхнях з розплющеними та заплющеними очима, $p < 0,001$). Отримані дані свідчать про те, що травми колінного суглоба призводять до значних порушень контролю рівноваги, що може негативно впливати на показники загальної спортивної результативності та ризик отримання травм.

Висновок. Дослідження підкреслює необхідність впровадження цілеспрямованих балансувальних та пропріоцептивних тренувань до програм реабілітації тенісистів, які відновлюються після отримання травм колінного суглоба. Шляхом поліпшення рівноваги такі інтервенції сприяють посиленню нервово-м'язового контролю, знижують ризик повторного травмування та забезпечують кращі показники загальної результативності в умовах підвищених навантажень. Майбутні дослідження мають бути зосереджені на вдосконаленні тренувальних програм з розвитку рівноваги з метою максимізації результатів відновлення та мінімізації наслідків травм.

Ключові слова: тенісисти, рівновага, травма колінного суглоба, ризик для здоров'я, постуральне коливання.

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Determining Reaction Time and Strength in Indonesian Male Badminton Athletes: Regional, National and Olympic Levels

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Abstract

Objectives. The study aimed to analyse the difference in whole-body reaction (WBR) times and the expanding strength of badminton athletes at regional, national, and Olympic levels.

Materials and methods. The study subjects consisted of 24 male athletes. Audio and visual whole-body reaction measurements were carried out, and each athlete's pull and push strength was expanded to analyse the existing differences. The data was analysed using One-Way ANOVA to determine the differences between the three sample groups.

Results. The results showed a significant difference ($p < 0.05$) in visual whole-body reaction and shoulder arm thrust force. Although, the audio whole body reaction variable and shoulder arm tensile strength did not significantly differ ($p > 0.05$).

Conclusions. The study indicated that badminton athletes' visual whole-body reaction speed was found to be better compared to their audio whole-body reaction speed ability. Additionally, Olympic athletes demonstrated enhanced strength conditions than regional and national-level athletes. The findings of this study are anticipated to help coaches in developing and implementing training programmes appropriate to the specific needs and conditions of athletes at the level of competition in which they are engaged.

Keywords: physical fitness, reaction speed, racket sport, elite athlete, junior athlete, young athlete.

Introduction

To succeed as a badminton athlete, one must consider physical condition. Elite athletes usually have better physical (Riccardo Izzo et al., 2018; Demirkan et al., 2015) and emotional (Mitić et al., 2021) conditions than non-elite athletes. Other factors that can influence an athlete's success include technique, tactics, psychology (Almagro et al., 2020), personality (Shuai et al., 2023), lifestyle, and mindset (Gontijo et al., 2023). Among all these aspects, one of the most determining and essential things to consider is physical condition, which can determine the competitive ability of athletes (R. Liu et al., 2022). Research states that physical fitness can also affect the technical abilities of athletes (Farley et al., 2020). Examples of parameters that can be used to measure the level of an athlete's physical condition are the reaction speed and strength of the athlete.

The reaction speed and strength of athletes play a crucial role in athlete performance (Lempke et al., 2020;

Suchomel et al., 2021). Athletes are required to have good reaction speed and strength to compete well. It is because the physical condition of athletes can be an indicator of their performance (Prasetyo, 2023). Training players' technical, tactical, and motivational abilities are essential to improve their performance to reach a higher level of play (Özgür et al., 2020). The need for strength and reaction speed varies according to the level of competition in which they participate.

As the level of competition increases, their abilities must also be improved. Other components that affect a person's physical condition are endurance, flexibility, and coordination. With good physical condition, a person's physical fitness will automatically increase. Good physical condition will make the athlete more likely to advance towards the final (Drid et al., 2015). Research also shows that athletes who compete at a higher level will have a better physical condition category (Drid et al., 2015).

However, many coaches and athletes only carry out and run training programs if they know whether the program can improve the athlete's abilities and whether these abilities are sufficient to compete with their opponents in the

competition later. Most coaches do not conduct physical tests on their athletes before and after running a training program, so the coach needs to know how to improve their athletes' abilities. In addition, they will need to find out whether the training program they have given athletes so far has been running effectively, which can help athletes achieve their best performance.

Most physical tests are only carried out when they are about to start competing by the organisation that oversees them. In addition, the general condition of the athlete can be seen through several studies that have been conducted. Several studies have been conducted on badminton athletes that can be used to determine the general condition of badminton athletes. Test items used to measure the fitness or ability of athletes can be developed by considering similar movements during the match (Ando et al., 2024). A study examining the physical development of young elite athletes revealed that within a 15-month gap in physical development in height, weight, left shoulder flexion, and grip strength in male athletes, meanwhile height, medicine ball throws, and counter-movement jumps in female athletes (Henn, 2021). Another study on Indonesian badminton athletes with intellectual disabilities stated that athletes' endurance, strength, speed, flexibility, and coordination abilities were in the poor category (Tyas et al., 2021). A study comparing the physical condition of young elite athletes in Indonesia and Turkey stated that the strength abilities of Turkish athletes were much better when compared to Indonesian athletes (Özgür et al., 2020).

Based on several studies on the physical condition of badminton athletes that have been conducted previously. However, studies have yet to compare the physical condition of badminton athletes at several different levels of competition. Therefore, the novelty of this study is using badminton athlete samples from 3 different levels of competition, namely regional, national, and Olympic, to obtain data. This study aims to analyse the differences in physical conditions possessed by athletes from three different levels of competition. This study will focus on analysing differences in physical conditions regarding reaction speed and strength possessed by athletes from the three existing groups. This study is expected to help coaches know the physical condition of athletes on the field and help coaches compile training programs that follow the needs and conditions of their athletes so that the results of training and athlete performance can be achieved optimally.

Materials and Methods

Study Participants

The sample population is male badminton athletes in Indonesia, starting at regional, national, and Olympic levels.

Table 2. Data Significance Test

No	Variabel Test	ANOVA					Annotation
		Sum of Squares	df	Mean Square	F	Sig.	
1.	Audio WBR	0.001	2	0.001	1.099	0.352	sig. > 0.05 (No Significance)
2.	Visual WBR	0.018	2	0.009	13.559	0.000	
3.	Expanding Strength (Pull)	528.243	2	264.122	3.432	0.051	sig. < 0,05 (Significance)
4.	Expanding Strength (Push)	2165.249	2	1082.625	17.698	0.000	

The sampling technique used is stratified random sampling with a sample size of 24 male athletes with details of 11 regional, eight national, and five Olympic athletes. The athletes used as samples in the study have won a championship and qualified for the next level of competition, both competitions at the regional, national, and Olympic levels.

Study Organization

Each athlete will take a test to measure their audio and visual reaction speed as well as their expanding strength in pulling and pushing. The tool used in whole-body reaction test is TKK1264P model. The test used will use the sense of hearing as a stimulus receptor with a stimulus in the form of sound and the sense of sight as a stimulus receptor with light as the stimulus used. An expanding dynamometer measures the expanding strength of pulling and pushing. This research complies with the seven WHO 2011 Standards and has been declared ethically acceptable by ethics committee of Universitas Negeri Surabaya No.006/UN38.III.1/DL.01.02./2024.

Statistical Analysis

This research uses IBM SPSS Statistics version 25 to help with the data analysis. The Shapiro-Wilk test was used to determine data normality, and One-Way ANOVA was used to test for significant differences between the three sample groups.

Results

Table 1. Sample Profil

No.	Characteristic	N	Min	Max	Mean	SD
1.	Age	24	14	31	21.2917	5.63745
2.	Height	24	154.50	183.00	174.3875	6.50420
3.	Weight	24	46.00	88.30	70.2125	9.57398
4.	IMT	24	19.00	28.00	21.2917	5.63745

Table 1 shows the characteristics of the samples used. The athletes analysed ranged from teenagers to adults. There is also a relatively significant difference in the variables of weight and height, considering the relatively significant age difference. Based on the analysis carried out, after the data was declared normal, the analysis process was continued to the next stage to determine the significance of the existing data.

From the results of the significance test in Table 2, it is known that 3 test variables have results where there are significant differences between the test results owned by

athletes from three different competition levels. The test variables are audio WBR and push expanding strength. Other results obtained from Table 2 are that other test variables show no significant differences in athletes competing in the three competition groups. The variables are audio WBR and pull expanding strength.

Based on Table 2, it is known that there are significant differences ($p = 0.000$) in the visual WBR variable. While in the audio WBR variable, no significant differences were found ($p = 0.352$). It proves that the three groups have prominent differences in visual reaction speed abilities, but there are no significant differences in audio reaction speed abilities. The data obtained from the test results show that in the visual WBR variable, athletes at the Olympic level have the lowest abilities. Meanwhile, in the WBR audio variable, the athlete's ability at a higher level of competition will decrease.

The data in Table 2 show that the push expanding strength variable has significant results ($p = 0.000$), which means there is a significant difference in the push expanding strength in athletes from the three competition groups. Meanwhile, the pull expanding strength variable shows no significant difference ($p = 0.051$). Although it has different results, something interesting about the expanding strength variable is that the test results data show that the athlete's expanding strength ability increases with the increase in the competition level, both for the pulling and pushing categories.

Discussion

The findings obtained in this study stated significant differences ($p < 0.05$) owned by regional, national, and Olympic athletes in the variables of visual WBR and push expanding strength. There were no significant differences in the variables of audio WBR and pull expanding strength ($p > 0.05$).

Whole Body Reaction

Coordination is a crucial factor in achieving success in badminton (Donie et al., 2023; Jaworski et al., 2021). Research shows that amateur badminton players do not have good balance, agility, and eye-hand coordination even though they perform better sports (Wong et al., 2019). The research has proven that playing experience significantly affects the coordination abilities of badminton athletes (Jaworski et al., 2017).

One aspect included in athlete coordination is reaction speed. An athlete's body reaction time has a very crucial impact on an athlete's performance on the field (Lempke et al., 2020; Yildiz et al., 2020). One of the factors that influences reaction time is the athlete's physical condition. The better an athlete's physical condition, the better their reaction speed will be (Hamidur Rahman et al., 2021). Reaction speed is the time between a given stimulus and a series of movements carried out due to that stimulus (Bańkosz et al., 2020; Ervilha et al., 2020).

Research reveals that reaction speed plays a vital role in achieving success in badminton, along with the techniques and tactics possessed in the game (Yüksel et al., 2018). Research on reaction time speed between athletes and non-athletes states that their audio reaction speed is faster when

compared to their visual reaction speed (Hamidur Rahman et al., 2021). Similar research on hockey players also showed that their reaction speed abilities were better when compared to visual reaction speed (Avci et al., 2023). It has findings that are contrary to the research conducted, that badminton athletes from regional, national, and Olympic levels have better visual reaction speed results when compared to their audio reaction speed. Several factors can affect visual reaction speed, including the dominant hand, colour, stimulus possibilities, and arrangement models (M. Liu et al., 2021). Meanwhile, factors that can affect audio reaction speed are age, gender, dominant hand, central versus peripheral vision, fatigue, respiratory cycle, fasting, personality, sports activity, and a person's intelligence (Jain et al., 2015).

The results found on WBR show that athletes at the regional, national, and Olympic levels have better visual WBR abilities than audio WBR. The results state that athletes at the Olympic level have the lowest reaction speed compared to athletes from regional and national levels. This could be due to their more mature age, which decreases their reaction speed.

In addition, the audio WBR results found that athletes in the regions had the best audio WBR abilities of the three groups of athletes and audio WBR abilities were lower at higher competition levels. It indicates that athletes' ability to respond via audio will decrease as they age. This condition can occur because their hearing and movement abilities are decreasing.

Another interesting result from the visual WBR and audio WBR of the three groups of athletes is that their visual reaction speed has better results when compared to their audio reaction speed. It proves that badminton athletes from all three levels of competition respond faster through sight than hearing. In badminton, athletes rely more on their sight to respond to the opponent's shuttlecock hit.

With this reality, existing coaches can create training programs that focus more on the speed of athletes' visual reactions because, in matches, visual reaction speed is very crucial and is more reliable to be able to respond to an opponent's hits than audio reaction speed for both regional and Olympic athletes. In addition, training programs that focus on reaction speed must be further improved for athletes with increasingly mature ages, considering that as age increases, athletes' reaction speed abilities will decrease. Several factors affect reaction speed, including the magnitude of the stimulus, age, gender, and level of fatigue (Pavelka et al., 2020). One way to increase the reaction speed of athletes is by doing motor imagery (Fekih et al., 2020) and plyometric training (Deng et al., 2024).

Expanding Strength

In addition to reaction speed, an athlete's strength ability also plays a vital role in an athlete's performance on the field. Good strength ability will minimise injuries when playing (Cuthbert et al., 2021; Lauersen et al., 2018; Talpey et al., 2017). The strength can also affect the athlete's skill ability (Suchomel et al., 2016). Warming up before doing activities can be a factor that can affect an athlete's strength ability (Resende et al., 2020).

Research on strength reveals that elite athletes have better strength abilities when compared to sub-elite athletes (Beddows et al., 2020). These findings align with research findings, that the athlete's strength and ability increase with

the competition level. Similar results are also found in other studies, which state that elite athletes have better strength than sub-elite and amateur players (Guðmundsdóttir et al., 2017). Research on leading and substitute athletes shows that main players have better strength abilities (Kim et al., 2019). The differences between athletes at different levels are likely due to the process of maturity and body mass.

In contrast, as competition increases, the chronological age and age of the athlete also increase. Research has shown that older players have better strength abilities (Peeters et al., 2023). The higher the level of competition, the greater the athlete's training load will be. The increase and high training load will increase muscle mass (Lopez et al., 2021), which will affect their strength abilities.

The results obtained on expanding strength state that the athlete's strength ability improves as the competition level increases. This proves that better strength abilities are needed at a higher level of competition. In addition, it shows that athletes with better-expanding strength abilities will have more potential to reach a higher level of competition.

Expanding strength is related to hitting ability in badminton athletes. It means that the hitting ability of Olympic athletes is better and more robust than that of regional and national athletes. Coaches can design training programs to improve athletes' strength and performance, enhancing their chances of advancing to the next level of competition. Some ways to increase athlete strength are resistance training (Krzysztofik et al., 2019), weight training (Nasrulloh et al., 2022), and velocity-based training (VBT) (Włodarczyk et al., 2021).

In badminton, players must display optimal performance, be able to move quickly (Phomsoupha et al., 2015), and have good power (Deng et al., 2024). Coordination is also a crucial factor in success in badminton (Donie et al., 2023; Jaworski et al., 2021). Research shows that amateur badminton players do not have good balance, agility, and eye-hand coordination performance even though they show better sports performance (Wong et al., 2019). Based on this, it is essential for badminton athlete coaches to continue to monitor the condition of their athletes in various factors to improve their abilities and achieve their peak performance. This research is expected to help coaches understand the condition of their athletes among athletes at various levels of competition. In addition, it is expected that after understanding the physical condition of athletes, coaches will also compile and develop training programs that are appropriate to the conditions of each individual. Many coaches still equate training programs for their athletes on the field. It was discovered that each athlete has a different physical condition, so they require different treatments.

With the rapid development of badminton and science and technology, of course, further research is needed to improve the quality of the game and utilise the development of technology and existing science to improve the quality of players. The large number of badminton players who have emerged from various circles, both children and adults and men and women, is a limitation in this study. The sample used in the study was still limited to male athletes, teenagers and adults. In further research to be conducted, it is hoped that the sample scope will be increased and expanded, both in terms of age and gender, so that the research results can be used to present all existing groups.

Conclusions

This study concludes that there are significant differences among male badminton athletes at the regional, national, and international levels in visual WBR and push-expanding strength. The strength ability of groups with higher levels of competition will have better results. In the WBR variable, the results were found that badminton athletes' visual WBR abilities were faster than audio WBR abilities. It occurs because the training load and age are different among the three groups of athletes. In the audio WBR and pull expanding strength variable, no significant differences were found between the three groups of athletes.

After conducting the study, it is hoped that coaches can adjust the training program according to the conditions and needs of each athlete due to differences in physical condition between one athlete and another. With a training program that follows the needs and portions of each athlete, the final results and objectives can be achieved optimally, and athletes will be able to achieve their best performance.

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Conflict of interest

All authors declare no conflicts of interest.

References

- Riccardo Izzo, Angelo De Vanna, & Ciro Hosseini Varde'i. (2018). Data Comparison between Elite and Amateur Soccer Players by 20 Hz GPS Data Collection. *Journal of Sports Science*, 6(1). <https://doi.org/10.17265/2332-7839/2018.01.004>
- Demirkan, E., Koz, M., Kutlu, M., & Favre, M. (2015). Comparison of Physical and Physiological Profiles in Elite and Amateur Young Wrestlers. *Journal of Strength and Conditioning Research*, 29(7), 1876-1883. <https://doi.org/10.1519/JSC.0000000000000833>
- Mitić, P., Nedeljković, J., Bojanić, Ž., Frančeško, M., Milovanović, I., Bianco, A., & Drid, P. (2021). Differences in the Psychological Profiles of Elite and Non-elite Athletes. *Frontiers in Psychology*, 12, 635651. <https://doi.org/10.3389/FPSYG.2021.635651>
- Almagro, B. J., Sáenz-López, P., Fierro-Suero, S., & Conde, C. (2020). Perceived Performance, Intrinsic Motivation and Adherence in Athletes. *International Journal of Environmental Research and Public Health*, 17(24), 1-14. <https://doi.org/10.3390/IJERPH17249441>
- Shuai, Y., Wang, S., Liu, X., Kueh, Y. C., & Kuan, G. (2023). The influence of the five-factor model of personality on performance in competitive sports: a review. *Frontiers in Psychology*, 14. <https://doi.org/10.3389/FPSYG.2023.1284378>
- Gontijo, G. M., Ishikawa, V. N., Ichikawa, A. I. T., Bubna, P., Conter, F. da S., Queiroz, A. C. M. de, Picchia, R. Del, Silva, D. D. da, & Uliana Filho, I. I. (2023). Influences of

- mindset and lifestyle on sports performance: a systematic review. *International Journal of Nutrology*, 16(2). <https://doi.org/10.54448/IJN23227>
- Liu, R., & He, L. (2022). The relationship between physical fitness and competitive performance of Taekwondo athletes. *PLoS ONE*, 17(6). <https://doi.org/10.1371/JOURNAL.PONE.0267711>
- Farley, J. B., Stein, J., Keogh, J. W. L., Woods, C. T., & Milne, N. (2020). The Relationship Between Physical Fitness Qualities and Sport-Specific Technical Skills in Female, Team-Based Ball Players: A Systematic Review. *Sports Medicine - Open*, 6(1), 1-20. <https://doi.org/10.1186/S40798-020-00245-Y/TABLES/7>
- Lempke, L. B., Howell, D. R., Eckner, J. T., & Lynall, R. C. (2020). Examination of Reaction Time Deficits Following Concussion: A Systematic Review and Meta-analysis. *Sports Medicine*, 50(7), 1341-1359. <https://doi.org/10.1007/S40279-020-01281-0/TABLES/4>
- Suchomel, T. J., Nimphius, S., Bellon, C. R., Hornsby, W. G., & Stone, M. H. (2021). Training for Muscular Strength: Methods for Monitoring and Adjusting Training Intensity. *Sports Medicine*, 51(10), 2051-2066. <https://doi.org/10.1007/S40279-021-01488-9>
- Prasetyo. (2023). Proceedings of the 6th Yogyakarta International Seminar on Health, Physical ... - Google Books. Retrieved from <https://books.google.com/books?id=JbjeEAAAQBAJ>
- Özgür, B., & Üniversitesi, M. A. (2020). Comparison of Selected Physical Performance Characteristics of Elite Young Turkish and Indonesian Badminton Players. *International Journal of Applied Exercise Physiology*, 9(7). Retrieved from <https://www.researchgate.net/publication/344162222>
- Drid, P., Casals, C., Mekic, A., Radjo, I., Stojanovic, M., & Ostojic, S. M. (2015). Fitness and Anthropometric Profiles of International vs. National Judo Medalists in Half-Heavyweight Category. *Journal of Strength and Conditioning Research*, 29(8), 2115-2121. <https://doi.org/10.1519/JSC.0000000000000861>
- Ando, R., Hoshikawa, Y., Iizuka, T., Suita, M., Kameda, M., Nakashima, H., & Ozaki, H. (2024). Difference in badminton-specific endurance evaluated by a newly developed on-court test between competitive levels: A pilot study of female players. *Physiological Reports*, 12(10). <https://doi.org/10.14814/PHY2.16058>
- Henn, R. P. (2021). *Anthropometric and physical fitness characteristics of badminton players in Icelandic youth national teams*. Retrieved from <https://skemman.is/handle/1946/39501>
- Tyas, D., Phytanza, P., Burhaein, E., Cristina, C., Lourenço, V., Widodo, P., Prasetyo Widiyono, I., Irawan, Y. F., Sutopo, W. G., Saleh, M., Parmadi, M., & Azizah, A. R. (2021). Profile of physical condition of indonesian intellectually disabled badminton athletes during the covid-19 pandemic. *Sport Science*, 15(1), 168-177.
- Donie, Shapie, M. N. M., Okilanda, A., Edmizal, E., Suryadi, D., & Suganda, M. A. (2023). Concentration, eye coordination and agility: How they influence badminton playing skills. *Journal of Physical Education and Sport*, 23(12), 3309-3317. <https://doi.org/10.7752/JPEs.2023.12378>
- Jaworski, J., Lech, G., Ambroży, T., & Żak, M. (2021). Identification of coordination motor abilities determining the sports skill level in elite male badminton players. *Hum Mov*, 22(1), 9-15. <https://doi.org/10.5114/hm.2021.98459>
- Wong, T. K. K., Ma, A. W. W., Liu, K. P. Y., Chung, L. M. Y., Bae, Y. H., Fong, S. S. M., Ganesan, B., & Wang, H. K. (2019). Balance control, agility, eye-hand coordination, and sport performance of amateur badminton players: A cross-sectional study. *Medicine*, 98(2). <https://doi.org/10.1097/MD.00000000000014134>
- Jaworski, J., Lech, G., Żak, M., Madejski, E., & Szczepanik, K. (2017). The level of selected coordination abilities in badminton players at various ages and sport skill levels as compared to non-athletes. *Baltic Journal of Health and Physical Activity*, 9(3), 33-43. <https://doi.org/10.29359/BJHPA.09.3.03>
- Yildiz, S., Ates, O., Gelen, E., Cirak, E., Bakici, D., Sert, V., Kayihan, G., & Ozkan, A. (2020). The relationship between reaction time, agility and speed performance in high-level soccer players. *Acta Medica Mediterranea*, 36(5), 2923-2927. https://doi.org/10.19193/0393-6384_2020_5_448
- Rahman, Md. H., & Shahidul Islam, M. (2021). Investigation of Audio-Visual Simple Reaction Time of University Athletes and Non-Athletes. *Journal of Advances in Sports and Physical Education*, 4(3), 24-29. <https://doi.org/10.36348/jaspe.2021.v04i03.002>
- Bańkosz, Z., Winiarski, S., & Lanzoni, I. M. (2020). Gender Differences in Kinematic Parameters of Topspin Forehand and Backhand in Table Tennis. *International Journal of Environmental Research and Public Health*, 17(16), 1-12. <https://doi.org/10.3390/IJERPH17165742>
- Ervilha, U. F., Fernandes, F. de M., Souza, C. C. de, & Hamill, J. (2020). Reaction time and muscle activation patterns in elite and novice athletes performing a taekwondo kick. *Sports Biomechanics*, 19(5), 665-677. <https://doi.org/10.1080/14763141.2018.1515244>
- Yüksel, M. F., & Tunç, G. T. (2018). Examining the Reaction Times of International Level Badminton Players Under 15. *Sports*, 6(1). <https://doi.org/10.3390/SPORTS6010020>
- Avcı, N., Özdal, M., Yilmaz, Ö. F., Koyunlu, A., & Çağdanlioğlu, M. B. (2023). Investigation of Visual and Auditory Reaction Times of Elite and Non-Elite Field Hockey Athletes. *CBÜ Beden Eğitimi ve Spor Bilimleri Dergisi*, 18(2), 862-870. <https://doi.org/10.33459/cbubesbd.1242670>
- Liu, M., Lu, J., Gu, Y., Gao, C., & Lv, W. (2021). Research and Analysis on the Influence Factors of Visual Reaction Time. *Advances in Intelligent Systems and Computing*, 141-146. https://doi.org/10.1007/978-3-030-51041-1_20
- Jain, A., Bansal, R., Kumar, A., & Singh, K. (2015). A comparative study of visual and auditory reaction times on the basis of gender and physical activity levels of medical first year students. *International Journal of Applied and Basic Medical Research*, 5(2), 124. <https://doi.org/10.4103/2229-516X.157168>
- Pavelka, R., Třebický, V., Fialová, J. T., Zdobinský, A., Coufalová, K., Havlíček, J., & Tufano, J. J. (2020). Acute fatigue affects reaction times and reaction consistency in Mixed Martial Arts fighters. *PLOS ONE*, 15(1), e0227675. <https://doi.org/10.1371/JOURNAL.PONE.0227675>

- Fekih, S., Zguira, M. S., Koubaa, A., Ghariani, I., Zguira, H., Bragazzi, N. L., & Jarraya, M. (2020). The Impact of a Motor Imagery-Based Training Program on Agility, Speed, and Reaction Time in a Sample of Young Tennis Athletes during Ramadan Fasting: Insights and Implications from a Randomized, Controlled Experimental Trial. *Nutrients*, 12(11), 3306. <https://doi.org/10.3390/NU12113306>
- Deng, N., Soh, K. G., Abdullah, B. B., & Huang, D. (2024). Effects of plyometric training on skill-related physical fitness in badminton players: A systematic review and meta-analysis. *Heliyon*, 10(6), e28051. <https://doi.org/10.1016/j.heliyon.2024.e28051>
- Cuthbert, M., Haff, G. G., Arent, S. M., Ripley, N., McMahon, J. J., Evans, M., & Comfort, P. (2021). Effects of Variations in Resistance Training Frequency on Strength Development in Well-Trained Populations and Implications for In-Season Athlete Training: A Systematic Review and Meta-analysis. *Sports Medicine*, 51(9), 1967-1982. <https://doi.org/10.1007/S40279-021-01460-7>
- Lauersen, J. B., Andersen, T. E., & Andersen, L. B. (2018). Strength training as superior, dose-dependent and safe prevention of acute and overuse sports injuries: a systematic review, qualitative analysis and meta-analysis. *British Journal of Sports Medicine*, 52(24), 1557-1563. <https://doi.org/10.1136/BJSPORTS-2018-099078>
- Talpey, S. W., & Siesmaa, E. J. (2017). Sports Injury Prevention: The Role of the Strength and Conditioning Coach. *Strength and Conditioning Journal*, 39(3), 14-19. <https://doi.org/10.1519/SSC.0000000000000301>
- Suchomel, T. J., Nimphius, S., & Stone, M. H. (2016). The Importance of Muscular Strength in Athletic Performance. *Sports Medicine (Auckland, N.Z.)*, 46(10), 1419-1449. <https://doi.org/10.1007/S40279-016-0486-0>
- Resende, M. de A., Resende, R. B. V., Reis, G. C., Barros, L. de O., Bezerra, M. R. S., de Matos, D. G., Marçal, A. C., de Almeida-Neto, P. F., Cabral, B. G. de A. T., Neiva, H. P., Marinho, D. A., Marques, M. C., Reis, V. M., Garrido, N. D., & Aidar, F. J. (2020). The Influence of Warm-Up on Body Temperature and Strength Performance in Brazilian National-Level Paralympic Powerlifting Athletes. *Medicina*, 56(10), 538. <https://doi.org/10.3390/MEDICINA56100538>
- Beddows, T. P. A., van Klij, P., Agricola, R., Tak, I. J. R., Piscaer, T., Verhaar, J. A. N., & Weir, A. (2020). Normal values for hip muscle strength and range of motion in elite, sub-elite and amateur male field hockey players. *Physical Therapy in Sport*, 46, 169-176. <https://doi.org/10.1016/J.PTSP.2020.08.014>
- Guðmundsdóttir, A. M., Saavedra, J. M., & Einarsson, I. Þ. (2017). *Anthropometric and physical characteristics of elite, sub-elite and recreational Icelandic badminton players*. Retrieved from <https://skemman.is/handle/1946/29659>
- Kim, J. T., Shin, Y. A., Lee, K. H., & Rhyu, H. S. (2019). Comparison of performance-related physical fitness and anaerobic power between Korean wheelchair badminton national and backup players. *Journal of Exercise Rehabilitation*, 15(5), 663. <https://doi.org/10.12965/JER.1938448.224>
- Peeters, A., Leduc, C., Piscione, J., Lacombe, M., Carling, C., & Babault, N. (2023). Anthropometric and physical characteristics in U16, U18 and U20 elite French youth rugby union players. *PloS One*, 18(12). <https://doi.org/10.1371/JOURNAL.PONE.0295623>
- Lopez, P., Radaelli, R., Taaffe, D. R., Newton, R. U., Galvão, D. A., Trajano, G. S., Teodoro, J. L., Kraemer, W. J., Häkkinen, K., & Pinto, R. S. (2021). Resistance Training Load Effects on Muscle Hypertrophy and Strength Gain: Systematic Review and Network Meta-analysis. *Medicine and Science in Sports and Exercise*, 53(6), 1206. <https://doi.org/10.1249/MSS.0000000000002585>
- Krzysztofik, M., Wilk, M., Wojdała, G., & Gołaś, A. (2019). Maximizing Muscle Hypertrophy: A Systematic Review of Advanced Resistance Training Techniques and Methods. *International Journal of Environmental Research and Public Health*, 16(24). <https://doi.org/10.3390/IJERPH16244897>
- Nasrulloh, A., Prasetyo, Y., Nugroho, S., Yuniana, R., & Wahyudin Pratama, K. (2022). The effect of weight training with compound set method on strength and endurance among archery athletes. *Journal of Physical Education and Sport * (JPES)*, 22(6), 1457-1463. <https://doi.org/10.7752/jpes.2022.06183>
- Włodarczyk, M., Adamus, P., Zieliński, J., & Kantanista, A. (2021). Effects of Velocity-Based Training on Strength and Power in Elite Athletes—A Systematic Review. *International Journal of Environmental Research and Public Health*, 18(10), 5257. <https://doi.org/10.3390/IJERPH18105257>
- Phomsoupha, M., & Laffaye, G. (2015). The Science of Badminton: Game Characteristics, Anthropometry, Physiology, Visual Fitness and Biomechanics. *Sports Medicine*, 45(4), 473-495. <https://doi.org/10.1007/S40279-014-0287-2>

Визначення часу реакції та силових показників індонезійських спортсменів-бадмінтоністів чоловічої статі: Регіональний, національний та олімпійський рівні

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

Реферат. Стаття: 7 с., 2 табл., 45 джерел.

Мета дослідження. Мета дослідження полягала в проведенні аналізу відмінностей у часі реакції всього організму (ЧРО) та збільшенні рівня силових показників спортсменів-бадмінтоністів на регіональному, національному та олімпійському рівнях.

Матеріали та методи. У дослідженні взяли участь 24 спортсмени чоловічої статі. Задля аналізу існуючих відмінностей проведено вимірювання слухової та зорової реакції всього організму, а також збільшено рівень сили тяги та поштовху кожного спортсмена. Отримані дані проаналізовано за допомогою однофакторного дисперсійного аналізу (ANOVA) з метою визначення відмінностей між трьома вибірковими групами.

Результати. За результатами дослідження було виявлено достовірну різницю ($p < 0,05$) у показниках зорової реакції всього організму та сили поштовху плечового поясу та рук. Однак істотних відмінностей у показниках змінної слухової реакції всього організму та сили розтягування плечового поясу та рук не спостерігалось ($p > 0,05$).

Висновки. Дослідження показало, що швидкість зорової реакції всього організму спортсменів-бадмінтоністів мала кращі показники порівняно зі здатністю до швидкості слухової реакції всього організму. Крім того, олімпійські спортсмени продемонстрували більш високі силові показники, ніж спортсмени регіонального та національного рівней. Отримані результати дослідження допоможуть тренерам у розробці та впровадженні тренувальних програм, що відповідають специфічним потребам і умовам спортсменів на рівні змагань, в яких вони беруть участь.

Ключові слова: фізична підготовленість, швидкість реакції, ракетковий вид спорту, спортсмен високого класу, спортсмен-юніор, спортсмен молодого віку.

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Concept of Plyometric Training and Its Effect on Physiological Parameters of Football Players

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Abstract

Background. Plyometric training, which consists of exercises that involve rapid and repetitive muscle stretching and contraction, has become increasingly popular for its potential in sports conditioning.

Objectives. The primary objective of this study was to examine the principles of plyometric training and to assess how it influences the physiological parameters of football players.

Materials and methods. This study involved 30 male football players aged 18 to 24, actively engaged in national-level competition. The participants were randomly divided into two groups: the experimental group (n = 15) and the control group (n = 15), with 15 players in each group. The selected physiological parameters for assessment included aerobic capacity, blood pressure, and pulse rate. Aerobic capacity was measured using Cooper's 12-minute run/walk test, blood pressure was assessed with a sphygmomanometer, and pulse rate was measured using the radial artery method. The six-week plyometric training program, conducted five days a week, involved 60-minute sessions. The experimental group underwent the plyometric training program, while the control group did not engage in any specific exercises. Pre- and post-test scores were analyzed statistically using descriptive statistics and analysis of covariance (ANCOVA). The significance level was set at a confidence level of 0.05.

Results. The findings indicate a notable enhancement in physiological parameters among participants in the experimental group as opposed to the control group. The implementation of the plyometric training program proved to be effective in elevating the aerobic capacity, blood pressure, and pulse rate of the football players.

Conclusions. The study concludes that a six-week plyometric training program significantly enhances the physiological parameters of football players, including aerobic capacity, blood pressure, and pulse rate. Further research should be conducted to examine the long-term effects and optimal duration of plyometric training, as well as the underlying physiological mechanisms, in order to gain a deeper understanding of its effectiveness and applications in sports conditioning.

Keywords: plyometric training, aerobic capacity, blood pressure, pulse rate, football.

Introduction

The term “plyometrics” originates from the Greek words “plythein” or “plyo,” meaning “to increase,” and “metric,” meaning “to measure.” Thus, plyometrics fundamentally implies “to increase the measurement.” This often refers to improvements

in sports performance metrics, such as throwing distance, serve velocity, jump height, or sprint speed, as measured during testing or competition (Davies et al., 1998). Plyometric training is typified by quick, strong motions that involve an explosive concentric contraction, which is a sudden, powerful shortening of the muscles after an initial lengthening (eccentric contraction). According to Bosco et al. (1982), this training technique can make use of either an eccentric-concentric coupling phase or a stretch-shortening cycle. The latter, sometimes referred to as the integrated performance paradigm,

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& Mola, D. W., 2024.



places emphasis on the necessity of precisely achieving movement by loading forces eccentrically, stabilizing isometrically, and then accelerating concentrically. Plyometric exercise, according to Voight and Brady (1992), uses the body's proprioceptive and elastic qualities to help generate maximum force in the shortest amount of time. By increasing the excitability, sensitivity, and reactivity of the neuromuscular system, this type of training not only increases motor learning but also neuromuscular efficiency. The overall impact includes an increase in the rate of force production (power), motor-unit recruitment, frequency (rate coding), and synchronization.

Plyometric exercises should be used for performance enhancement in sports because they incorporate principles essential to both lower extremity (LE) and upper extremity (UE) sports. Plyometric training leverages the stretch-shortening cycle (SSC), which involves a rapid transition from lengthening (eccentric) to shortening (concentric) movements (Ebben et al., 2008). This cycle enhances the efficiency and power of movements, leading to improved sports performance.

According to Chmielewski et al. (2006), plyometric training consists of three separate phases: the eccentric phase, the amortization phase, and the concentric phase. Muscles pre-extend before activating during the eccentric phase, which raises the activity of muscle spindles. The time between the end of the eccentric contraction (also known as the loading or deceleration phase) and the start of the concentric contraction (also known as the unloading or force production phase) is known as the amortization phase. Following the amortization phase, there is a concentric contraction during the concentric phase.

Plyometric training leverages the elastic and proprioceptive attributes of muscles to achieve maximal force production, stimulating mechanoreceptors and promoting increased muscle recruitment in a condensed timeframe, as indicated by Wilk et al. (1993). The proprioceptive foundation for plyometric training is provided by muscle spindles and Golgi tendon organs (GTOs). The central nervous system utilizes this sensory input to influence muscle tone, motor execution, and kinesthetic awareness, as elucidated by Lundin (1985). Activation of these receptors facilitates, inhibits, and modulates both agonist and antagonist muscle activities, thereby enhancing neuromuscular efficiency and functional strength.

Exercises that involve plyometric stabilization, plyometric strength, and plyometric power have three main contraindications. Exercises for plyometric stabilization are designed to improve reactive neuromuscular efficiency, postural alignment, and ideal landing mechanics. The goals of plyometric-strength workouts are to improve the neuromuscular efficiency of the human movement system overall, eccentric strength, dynamic joint stabilization, and rate of force output (Mola & Adane, 2020). Markovic et al. (2007) found that maximal speed and explosiveness are used when performing plyometric power exercises.

The contractile component of the actin and myosin cross bridges with the sarcomere plays an important role in motor control and force development during plyometrics. The plyometric movement uses the pre-stretch of the muscle-tendon unit physiological length-tension curve in order to enhance the ability of the muscle fibers to generate more tension and resultant force production (Davies et al., 2001).

Football, or soccer, stands as the most widely embraced team sport globally, recognized for its dynamic and fast-paced nature, captivating both players and spectators. The evolution

of football is marked by an increased emphasis on "high sports performance," wherein the game's essence involves the interplay of skill, technical and tactical prowess, motor component development, and physiological parameters. In addition to technical and physical advancements, there is a growing focus on enhancing the intellectual capacities of football players. Research by Singh et al. (2016; 2018) underscores the significance of various factors such as endurance, speed, agility, leg strength, upper body strength, power, muscular endurance, flexibility, coordination, and reaction time in optimizing football performance.

Football is acknowledged as one of the most intricate sports globally, demanding a synthesis of technical, tactical, and physical skills for success (Yi et al., 2018; Mola & Shaw, 2024). The collective performance of a team hinges on the cooperative dynamics among players in different positions, exemplified by midfielders orchestrating offense and defenders excelling in aerial duels and interceptions (Aquino et al., 2020; Modric et al., 2019). Understanding these position-specific demands becomes pivotal in evaluating player accomplishments (Dellal et al., 2010).

The contemporary landscape of football mandates elevated levels of endurance, speed, strength, and coordination skills, necessitating players to possess well-developed physical fitness (Chmura et al., 2015). Given that football primarily relies on aerobic metabolism for energy production (Silva et al., 2011), maintaining adequate aerobic fitness (AF) becomes crucial. A robust level of AF enables players to sustain high-intensity actions throughout a match, expedite recovery, and uphold peak physical condition throughout the season (Slimani et al., 2019).

Plyometric training, as highlighted by Patir et al. (2021), emerges as a training technique employed by athletes to enhance strength and explosiveness across various sports, including soccer. Recognizing soccer as a game demanding speed, agility, strength, power, endurance, and skill, the authors assert that plyometrics can contribute to improving soccer players' aerobic fitness. Soccer training is essentially a preparation process to enhance individual players' capabilities, enabling them to navigate the challenges of competitive matches successfully.

The physical demands of football encompass a variety of activities, from short sprints to recovery movements, necessitating both aerobic and anaerobic fitness (Williams et al., 2003; Reilly et al., 2000; Mola & Shaw, 2024; Singh et al., 2018; Fenta & Mola, 2023). Aerobic capacity, denoting a broad range of metabolic processes, plays a pivotal role in the total energy capacity of the human body. Maximal oxygen uptake ($\text{VO}_2 \text{ max}$), a measure of aerobic intensity, signifies the organism's ability to utilize the maximum amount of oxygen at a given moment (Rankovi et al., 2010). Blood pressure, recorded as systolic and diastolic pressures, and pulse rate, measured in beats per minute (bpm), are additional physiological parameters assessed in soccer players. Notably, trained soccer players often exhibit lower resting heart rates than their counterparts (Singh et al., 2022) – a key indicator of cardiovascular health.

Materials and Methods

Selection of Subjects

The study involved the participation of thirty male football players hailing from the Imphal East district of

Manipur, India. These individuals competed in the national competition, with their ages falling within the range of 18 to 24 years.

Selection of the Test

The study employed Cooper's 12-minute run/walk test to evaluate aerobic capacity, while blood pressure was measured using the sphygmomanometer method. Additionally, pulse rate was assessed using the radial artery method. These specific tests were selected as they provide accurate measures of the physiological parameters under investigation in this study.

Criterion Measures

The testing protocol for evaluating aerobic capacity, blood pressure, and pulse rate adheres to specific criteria. The assessment involves the utilization of Cooper's 12-minute run/walk test to gauge aerobic capacity, with results measured in minutes. Blood pressure is determined through the sphygmomanometer method, providing measurements in millimeters of mercury (mmHg). Pulse rate is recorded using the radial artery method, expressed in counts per minute. Adherence to these criteria is crucial to maintain precision in measurements and to ensure the reliability of the obtained results.

Design of the Study

The primary aim of this study was to examine the impact of a plyometric training program on the aerobic capacity, blood pressure, and pulse rate of football players. The research involved two groups of participants, randomly assigned for the investigation: an experimental group comprising 15 players and a control group consisting of 15 players. Prior to the implementation of the plyometric training program, baseline measurements were taken for the selected parameters in both groups. Aerobic capacity was assessed using Cooper's 12-minute run/walk test, while blood pressure and pulse rate were measured utilizing the sphygmomanometer method and the radial artery method, respectively. The plyometric training program spanned six weeks, with five training sessions per week, each lasting for 60 minutes. The experimental group adhered to the prescribed plyometric training regimen, while the control group continued with their regular match practice. The intervention period encompassed the timeframe from August 10 to October 10, 2023.

Inclusive and Exclusive Criteria

Participants were selected based on physical preparedness and health history questionnaires. Only those free from acute or chronic illnesses and without physical or psychological damage were included. The study ensured participant privacy and addressed ethical concerns, such as potential harm and data confidentiality. Those not meeting these criteria were excluded from the intervention.

Training Program

Training was carried out for the study's goal, and then a six-week plyometric training programmed. This training

regimen adhered to Thompson et al. (2013)'s prescribed allotment for exercise. Five times a week, the programmed comprised 60 minutes of exercise, consisting of a 10-minute warm-up, a 40-minute main activity, and a 10-minute warm-down. Five times a week for six weeks, the workout was done. By increasing the size and quantity of exercise motions, we have developed a programmed that remains within the bounds of the peak performance exercise intensity that was previously established (Singh, 2018). Furthermore, we prioritized safety over accuracy when rehearsing each man oeuvre, therefore we proposed slightly altering the movement in portions that were challenging to execute. The specifics of the weekly training schedule for the plyometric training programmed are outlined in Tables 1 and 2.

Table 1. Plyometric Training Program Design

No	Particulars	Duration
1.	Total program length	6 weeks
2.	Training frequency per week	5 days
3.	Duration of each training Session	45 minutes
4.	Rest interval between repetition	3 minutes
5.	Rest interval between exercises	1 minute
6.	Warm up and cooling down	15 minutes

Intensity

Intensity is the actual percentage of effort required by the footbllers to perform the activity. In plyometrics, the type of exercise performed controls the intensity. Plyometric exercises can come in many forms and intensities. Some activities such as bilateral jumping to a box are lower level plyometrics while others such as single leg jumps from a box are intense.

Volume

Volume is the total work performed in a single work session or cycle (periodization). In the case of plyometric training, volume is often measured by calculating the load, counting the number of repetitions, sets, etc. of the specific activity. Volume should be increased in a progressive manner to decrease risk of injury or overtraining.

Frequency

Frequency is the number of exercise sessions that take place during the training.

Recovery

Recovery is important to prevent injuries, overtraining and to determine the primary emphasis of the plyometric program. Because of the intense demands on the body with plyometric training, longer recovery periods between sets may be appropriate.

Statistical Analysis

The data collected were entered into an Excel spreadsheet, and statistical analyses were carried out using IBM SPSS

Table 2. Six-Week Plyometric Training Program

Weeks	Components of Plyometric Training	Repetition	Set	Intensity
1-2 Weeks	Squat jump & Tuck jump	2	2	40% to 50%
	Power skipping	2	2	40% to 50%
	Alternate leg bounding	2	2	40% to 50%
	Vertical depth jump: starting from the top of a box, jump down	2	2	40% to 50%
	Broad jump: Straddle jump, single and double leg hops up to 20 meters	2	2	40% to 50%
3-4 Weeks	Squat jump& Tuck jump	3	2	50% to 60%
	Power skipping	3	2	50% to 60%
	Alternate leg bounding	3	2	50% to 60%
	Vertical depth jump: starting from the top of a box, jump down	3	2	50% to 60%
	Broad jump: Straddle jump, single and double leg hops up to 20 meters	3	2	50% to 60%
5-6 Weeks	Squat jump& Tuck jump	4	2	60% to 70%
	Power skipping	4	2	60% to 70%
	Alternate leg bounding	4	2	60% to 70%
	Vertical depth jump: starting from the top of a box, jump down	4	2	60% to 70%
	Broad jump: Straddle jump, single and double leg hops up to 20 meters	4	2	60% to 70%

N.B.: – Low Intensity: 40% to 50%, Moderate intensity: 50% to 60% and High intensity: 60% to 70%

software (version 22.0; SPSS Inc., Chicago, IL, USA). Descriptive statistics were employed to analyze pre- and post-test scores, and differences among groups were examined using the analysis of covariance test (ANCOVA). The significance level for the statistical analyses was set at 0.05.

Ethical Approval

This study received approval from the Institutional Human Ethical Committee of Manipur University, Canchipur, Imphal (India), with Reference Number MU/IHEC/2022/021. Additionally, informed consent was duly obtained from all participants, ensuring compliance with ethical standards and respect for the participants' autonomy.

Results

The results of the study showed a significant improvement in the aerobic capacity of selected subjects of the experimental and control groups. Table 3 presents the

descriptive analysis of the data collected from the pre-test and post-test after six-weeks of plyometric training in the experimental and control groups.

Table 3 shows that the experimental group and control group achieved pre-test averages on aerobic capacity of 27.68 & 26.85. The obtained pre-test F-value of 1.780 and the necessary table F-value of 4.20 demonstrated that there was no statistically significant variation in the individuals' starting scores. The experimental group and control group achieved post-test averages on aerobic capacity of 29.82 & 28.25. The fact that the needed table F-value was 4.20 and the obtained post-test F-value was 15.730* demonstrated that there was a significant difference between the participants' post-test results. After determining the adjusted post-means tests for the pre-test and post-test means and performing an analysis of covariance, the obtained F-value of 52.24* was found to be greater than the required value of 4.20, indicating that there were significant differences between the treated groups. Additionally, Figure 1 displayed the mean aerobic capacity score for the experimental and control groups.

Table 3. Pre and post means score of aerobic capacity for experimental and control groups

Variable	Test	Experimental Group	Control Group	Source of Variance	Sum of Square	df	Mean Square	'F' Ratio
Aerobic Capacity	Pre test	27.68	26.85	Between	1.1483	2	1.1483	1.780
				Within	4.010	28	1.1220	
	Post test	29.82	28.25	Between	1.391	2	1.391	15.730*
				Within	4.627	28	4.627	
	Adjusted Post mean test	28.86	27.88	Between	63275.9	2	63275.9	52.24*
				Within	34642.4	27	2617.4	
	Mean Diff.	2.272	-2.272					

*Significant at .05 level, Table F-ratio at 0.05 level of confidence for 2 and 28 (df) = 4.20 and 27 (df) = 4.215

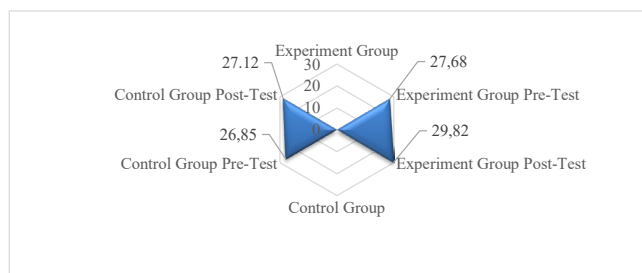


Fig. 1. Graphical presentation on pre and post means score of aerobic capacity for experimental and control group

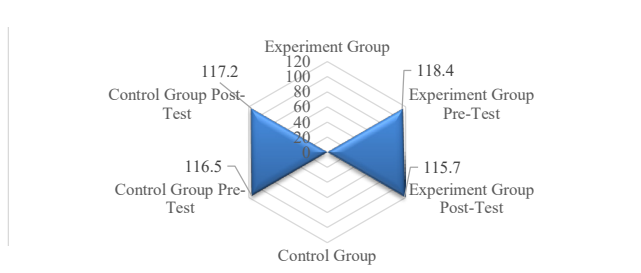


Fig. 2. Graphical presentation on pre and post means score of systolic blood pressure for experimental and control groups

Furthermore, the study's findings demonstrated that a subset of the experimental and control groups' systolic blood pressure significantly improved. Table 5 presents the descriptive analysis of the data obtained from the pre-test and post-test following six weeks of plyometric training for the experimental and control groups.

Table 5 shows that the experimental group and control group attained pre-test averages on Systolic Blood Pressure of 118.4 & 117.2. The fact that the needed table F-value was 4.20 and the achieved pre-test F-value of 4.00 demonstrated that there was no statistically significant difference between the individuals' starting scores. The experimental group and control group's post-test averages for Systolic Blood Pressure were 115.7 & 116.5. The fact that the needed table F-value was 4.20 and the obtained post-test F-value was 10.30* demonstrated that there was a significant difference between

the participants' post-test results. After determining the adjusted post-means test and doing a covariance analysis, it was recognized that there were significant differences between the treated groups because the obtained F-value of 20.24* was higher than the necessary value of 4.20. Additionally, Figure 2 displayed the mean Systolic Blood Pressure score for both the experimental and control groups.

Additionally, the study's findings demonstrated that a subset of the experimental and control groups' diastolic blood pressure significantly improved. Table 7 displays the results of the descriptive analysis of the data gathered from the pre-test and post-test following six weeks of plyometric training for the experimental and control groups.

Table 7 shows that the experimental group and the control group obtained pre-test averages on diastolic blood pressure of 80.4 & 82.3. The obtained pre-test F-value of

Table 4. Pairwise comparisons of experimental and control group of aerobic capacity of football players

Variable	Group	Mean Difference	Std. Error	Sig.b	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
Aerobic Capacity	Experimental Group	2.272	2.452	0.008	2.72	2.464
	Control Group	-2.272	2.452	0.008	-2.464	-2.72

Table 5. Pre and post means score of systolic blood pressure for experimental and control groups

Variable	Test	Experimental Group	Control Group	Source of Variance	Sum of Square	df	Mean Square	'F' Ratio
Systolic Blood Pressure	Pre test	118.4	117.2	Between	110.57	2	110.57	4.00
				Within	4.322	28	20.42	
	Post test	115.7	116.5	Between	116.453	2	116.453	10.30*
				Within	425.84	28	4.794	
	Adjusted Post mean test	117.96	115.88	Between	14151.9	2	14151.9	20.24*
				Within	2542.7	27	2312.8	
	Mean Diff.	5.648	-5.648					

*Significant at .05 level, Table F-ratio at 0.05 level of confidence for 2 and 28 (df) = 4.20 and 27 (df) = 4.215

Table 6. Pairwise comparisons of experimental and control groups of systolic blood pressure of football players

Variables	Group	Mean Difference	Std. Error	Sig.b	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
Systolic Blood Pressure	Experimental Group	5.648	3.035	0.034	1.689	8.296
	Control Group	-5.648	3.035	0.034	-8.296	-1.689

Table 7. Pre and post means score of diastolic blood pressure for experimental and control groups

Variables	Test	Experimental Group	Control Group	Source of Variance	Sum of Square	df	Mean Square	'F' Ratio
Diastolic Blood Pressure	Pre test	80.4	82.3	Between	40.13	2	40.13	3.50
				Within	76.94	28	4.52	
	Post test	78.2	79.6	Between	38.60	2	38.60	6.20*
				Within	78.342	28	60.654	
	Adjusted Post mean test	80.2	78.5	Between	48.653	2	48.653	10.15*
				Within	54.437	27	65.127	
	Mean Diff.	-2.14	-0.04					

*Significant at .05 level, Table F-ratio at 0.05 level of confidence for 2 and 28 (df) = 4.20 and 27 (df) = 4.215

Table 8. Pairwise comparisons of experimental and control groups of diastolic blood pressure of football players

Variable	Group	Mean Difference	Std. Error	Sig.b	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
Diastolic Blood Pressure	Experimental Group	3.252	1.868	0.501	1.183	5.263
	Control Group	-3.252	1.868	0.501	-5.263	-1.183

Table 9. Pre and post means score of pulse rate for experimental and control groups

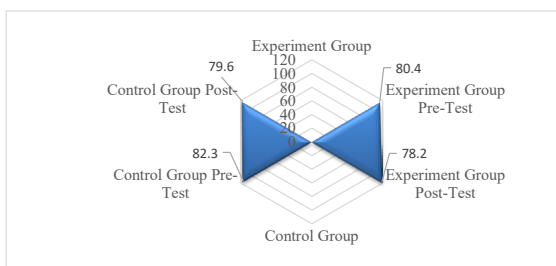
Variables	Test	Experimental Group	Control Group	Source of Variance	Sum of Square	df	Mean Square	'F' Ratio
Pulse Rate	Pre test	72.4	74.3	Between	140.43	2	140.43	2.10
				Within	23.94	28	19.52	
	Post test	68.2	70.6	Between	267.46	2	267.46	8.40*
				Within	130.16	28	18.50	
	Adjusted Post mean test	70.6	72.4	Between	245.73	2	245.73	12.14*
				Within	187.77	27	169.64	
	Mean Diff.	-2.14	-0.04					

*Significant at .05 level, Table F-ratio at 0.05 level of confidence for 2 and 28 (df) = 4.20 and 27 (df) = 4.215

Table 10. Pairwise comparisons of experimental and control group of pulse rate of football players

Variable	Group	Mean Difference	Std. Error	Sig.b	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
Pulse Rate	Experimental Group	8.645	2.364	0.02	6.136	12.172
	Control Group	-8.645	2.364	0.02	-12.172	-6.136

3.50 and the necessary table F-value of 4.20 demonstrated that there was no statistically significant value was 6.20* demonstrated that the individuals' post-test scores differed significantly from one another. After doing an analysis of covariance and compelling the adjusted post-means test to be considered, it was agreed that there were significant differences variation in the individuals' starting scores. The experimental group and control group's attained post-test averages for diastolic blood pressure were 78.2 & 79.6. The fact that the needed table F-value was 4.20 and the obtained post-test F-between the treated groups because the obtained F-value of 10.15* was higher than the necessary value of 4.20.

**Fig. 3.** Graphical presentation on pre and post means score of diastolic blood pressure for experimental and control groups

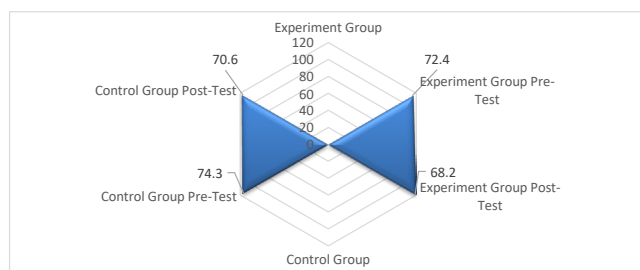


Fig. 4. Graphical presentation on pre and post means score of pulse rate for experimental and control group

Additionally, Figure 3 displayed the mean diastolic blood pressure score for both the experimental and control groups.

Additionally, the study's findings demonstrated that a subset of the experimental and control groups' pulse rates significantly improved. Table 9 presents the descriptive analysis of the data obtained from the pre-test and post-test following six weeks of plyometric training for the experimental and control groups.

Table 9 shows that the experimental group and control group attained pre-test averages on the pulse rate of 72.4 & 74.3. The obtained pre-test F-value of 2.10 and the necessary table F-value of 4.20 demonstrated that there was no statistically significant variation in the individuals' starting scores. The experimental group and control group achieved post-test averages on the pulse rate of 68.2 & 70.6. The fact that the needed table F-value was 4.20 and the obtained post-test F-value was 8.40* demonstrated that the individuals' post-test scores differed significantly from one another. After conducting an analysis of covariance and compelling the modified post-means test, it was concluded that there were significant differences between the treated groups. The obtained F-value of 12.14* was higher than the necessary value of 4.20. Additionally, Figure 4 displayed the average pulse rate score for both the experimental and control groups.

Discussion

Plyometric training involves quick, strong movements characterized by explosive concentric contractions, which are rapid muscle shortening following an initial lengthening (Islam et al., 2024). This research aimed to examine the principles of plyometric training and its effects on the physiological parameters of football players. The plyometric program lasted six weeks, with training sessions held five days a week (Monday to Friday) for 60 minutes each. The study found that plyometric training significantly impacted heart rate, blood pressure, and aerobic capacity. In contrast, the control group, which did not follow any specific training regimen, showed no improvement in these parameters. These findings were supported by statistical analyses, including descriptive statistics and ANCOVA.

The current study's results suggested that the influence of the plyometric training programme greatly enhanced all of the dependent variables. Shunmuganathan (2018) conducted a study to examine the impact of plyometric training on selected physiological variables among 30 adolescent school boys aged 14 to 18 years. The participants were divided into

two groups: Group A underwent six weeks of plyometric training, while Group B served as the control. The findings revealed a significant improvement in resting heart rate, systolic blood pressure, and diastolic blood pressure due to the six-week plyometric training program. Here's a paraphrased version: The study investigated how plyometrics, Pilates, and their combination impact vertical jump performance in basketball players. Dividing 45 subjects into plyometrics (Group A), Pilates (Group B), and combined training (Group C), the research found that after six weeks, Group C exhibited the most notable increases in vertical jump height and muscle endurance. This suggests that combining plyometrics with Pilates is more effective than either exercise alone for improving vertical jump performance (Chouhan et al., 2022).

Results indicated significant improvements in Pulse Rate and Vital Capacity for the Plyometric and Circuit training groups compared to the control, with no significant changes in Systolic and Diastolic Blood Pressure. Karup-pasamy (2018) investigated the impact of plyometric and circuit training on physical and physiological variables in 24 male volleyball players aged 18 to 25 years. The study demonstrated significant improvements in speed, muscular endurance, flexibility, agility, explosive strength, vital capacity, and anaerobic capacity following both plyometric and circuit training (Mola & Bayeta, 2020). Sivakumar and Logeswaran (2017) studied the effects of plyometric training on resting heart rate and breath-holding time in thirty adolescent male tennis players aged 14 to 17 years. The results showed significant improvements in both resting heart rate and breath-holding time after twelve weeks of plyometric training, highlighting a notable difference between experimental and control groups.

Anitha (2014) examined the effect of plyometric training on physiological variables in 30 inter-collegiate male volleyball players, demonstrating significant improvements in Breath Holding Time and Resting Heart Rate compared to the control group. Chandra et al. (2023) found that a 3-week plyometric training program significantly improved agility, speed, and explosive strength in badminton players compared to a control group, demonstrating the program's effectiveness. Kryeziu et al. (2023) found that a 12-week plyometric training program significantly improved speed and explosive strength in adolescent males compared to a control group. These improvements were evident in various speed and jumping tests, highlighting the effectiveness of plyometric exercises for enhancing athletic performance. Anitha et al. (2018) found that six weeks of plyometric and circuit training significantly improved speed, muscular endurance, flexibility, agility, explosive strength, vital capacity, and anaerobic capacity in male volleyball players aged 18-25, demonstrating the effectiveness of both training methods (Anitha et al., 2018). Singh L et al. (2018) explored the effects of twelve weeks of plyometric and weight training on physiological variables in 60 male football players, indicating reductions in resting pulse rate for both the plyometric and weight training groups compared to the control group. Patir et al. (2021) studied the effectiveness of a plyometric training program in increasing the muscular endurance of football players. Therefore, the six-week plyometric training program significantly impacts the physiological parameters of football players. This study focused on male football players, so future

research should include female football players and utilize larger sample sizes for better generalizability. Additionally, similar studies are recommended for other sports to enhance player performance.

Conclusion

The study concludes that a six-week plyometric training program positively influences the aerobic capacity, blood pressure, and pulse rate of football players. The findings highlight the importance of integrating plyometric training into football training regimens to enhance overall fitness. Coaches and trainers can gain valuable insights from this study for designing effective training programs. Future research should investigate the long-term effects and optimal duration of plyometric training for sustained benefits, as well as the underlying physiological mechanisms to better understand its effectiveness in sports conditioning.

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Conflicts of interest

The authors declare no conflicts of interest.

References

- Davies, G. J., Heiderscheit, B., & Clark, M. (1998). *Closed kinetic chain exercises-functional applications in orthopaedics*. Strength and Conditioning Applications in Orthopaedics. Orthopaedic Section, Home Study Course, LaCrosse, WI.
- Bosco, C., Viitasalo, J. T., Komi, P. V., & Luhtanen, P. (1982). Combined effect of elastic energy and myoelectrical potentiation during stretch-shortening cycle exercise. *Acta physiologica Scandinavica*, 114(4), 557-565. <https://doi.org/10.1111/j.1748-1716.1982.tb07024.x>
- Voight, M. L., & Brady, D. (1992). *Plyometrics* (4th ed.). Onalaska, WI: S&S Publishers.
- Ebben, W. P., Simenz, C., & Jensen, R. L. (2008). Evaluation of plyometric intensity using electromyography. *Journal of strength and conditioning research*, 22(3), 861-868. <https://doi.org/10.1519/JSC.0b013e31816a834b>
- Chmielewski, T. L., Myer, G. D., Kauffman, D., & Tillman, S. M. (2006). Plyometric exercise in the rehabilitation of athletes: physiological responses and clinical application. *The Journal of orthopaedic and sports physical therapy*, 36(5), 308-319. <https://doi.org/10.2519/jospt.2006.2013>
- Wilk, K. E., Voight, M. L., Keirns, M. A., Gambetta, V., Andrews, J. R., & Dillman, C. J. (1993). Stretch-shortening drills for the upper extremities: theory and clinical application. *The Journal of orthopaedic and sports physical therapy*, 17(5), 225-239. <https://doi.org/10.2519/jospt.1993.17.5.225>
- Lundin, P. E. (1985). A review of plyometric training. *National Strength and Conditioning Association Journal*, 7(3), 65-70. [https://doi.org/10.1519/0744-0049\(1985\)007<0069:ARO PT>2.3.CO;2](https://doi.org/10.1519/0744-0049(1985)007<0069:ARO PT>2.3.CO;2)
- D.W. Mola and Adane. Alemmebrat kiflu (2020). The Effect Of Explosive Power, Flexibility And Speed Training On Long Jump Performance: The Case Of Burayu Town Athletics Club. *IJPEFS*, 36(1), 71-80.
- Markovic, G., Jukic, I., Milanovic, D., & Metikos, D. (2007). Effects of sprint and plyometric training on muscle function and athletic performance. *Journal of strength and conditioning research*, 21(2), 543-549. <https://doi.org/10.1519/R-19535.1>
- Davies, G. J., & Matheson, J. W. (2001). Shoulder Plyometrics. *Sports Medicine and Arthroscopy Review*, 9, 1-18. <https://doi.org/10.1097/00132585-200101000-00001>
- Singh, L. S., & Lamani, G. (2016). A study of training load on selected physical and physiological variables of soccer players of Manipur State. *Academic Sports Scholars*, 5(1).
- Singh, L. S. (2018). *Effect of Training Load*. New Delhi: Friends Publication (India).
- Qing Yi, Hong Jia, Hongyou Liu & Miguel Ángel Gómez (2018). Technical demands of different playing positions in the UEFA Champions League. *International Journal of Performance Analysis in Sport*. <https://doi.org/10.1080/24748668.2018.1528524>
- Mola, D. W., & Shaw, D. (2024). Analyzing The Reliability And Validity Of Talent Identification Practices For Athletes: An Adaptation Study. *Educational Administration: Theory and Practice*, 30(5), 12277-12284. <https://doi.org/10.53555/kuey.v30i5.4248>
- Aquino, R., Carling, C., Palucci Vieira, L. H., Martins, G., Jabor, G., Machado, J., Santiago, P., Garganta, J., & Puggina, E. (2020). Influence of Situational Variables, Team Formation, and Playing Position on Match Running Performance and Social Network Analysis in Brazilian Professional Soccer Players. *Journal of strength and conditioning research*, 34(3), 808-817. <https://doi.org/10.1519/JSC.0000000000002725>
- Modric, T., Versic, S., Sekulic, D., & Liposek, S. (2019). Analysis of the Association between Running Performance and Game Performance Indicators in Professional Soccer Players. *International journal of environmental research and public health*, 16(20), 4032. <https://doi.org/10.3390/ijerph16204032>
- Dellal, A., Wong, D. P., Moalla, W., & Chamari, K. (2010). Physical and technical activity of soccer players in the French First League-with special reference to their playing position. *International SportMed Journal*, 11(2), 278-290.
- Chmura, P., Konefał, M., Kowalczyk, E., & Chmura, J. (2015). Distances covered above and below the anaerobic threshold by professional football players in different competitive conditions. *Central European Journal of Sport Sciences and Medicine*, 10(2), 25-31.
- Silva, J. F., Dittrich, N., & Guglielmo, L. G. A. (2011). Aerobic evaluation in soccer. *Revista Brasileira de Cineantropometria & Desempenho Humano*, 13(5), 384-391
- Slimani, M., Znazen, H., Miarka, B., & Bragazzi, N. L. (2019). Maximum Oxygen Uptake of Male Soccer Players According to their Competitive Level, Playing Position and Age Group: Implication from a Network Meta-

- Analysis. *Journal of human kinetics*, 66, 233-245.
<https://doi.org/10.2478/hukin-2018-0060>
- Patir, K., Singh, L. S., Singh, S. S., & Meitei, R. (2021). Effect of plyometric training on muscular power among school football players. *Kalyan Bharati*, September (7-8).
<https://doi.org/10.13140/RG.2.2.27720.44802>
- Williams, A.M., Ford, P., Reilly, T., & Drust, B. (Eds.). (2003). *Science and Soccer* (2nd ed.). Routledge.
<https://doi.org/10.4324/9780203417553>
- Reilly, T., Williams, A. M., Nevill, A., & Franks, A. (2000). A multidisciplinary approach to talent identification in soccer. *Journal of sports sciences*, 18(9), 695-702.
<https://doi.org/10.1080/02640410050120078>
- Mola, D. W., & Shaw, D. (2024). Significance of Managerial Skills for Talent Development in Ethiopian Athletes. *International Journal of Kinesiology and Sports Science*, 12(2), 21-29. <http://doi.org/10.7575/aiac.ijkss.v12n.2p.2>
- Singh, L. S., Lamani, G., Chandu, R., & Sharma, H. S. (2018). Study of training on physiological variables of football players. *Academic Sports Scholars*, 7(1), 1-7.
- Fenta, B. G., & Mola, D. W. (2023). Effect of eight-week callisthenics exercise on selected physical fitness quality and skill performance in handball. *Jurnal SPORTIF : Jurnal Penelitian Pembelajaran*, 9(3), 550-566.
https://doi.org/10.29407/js_unpgri.v9i3.21335
- Rankovic, G., Mutavdzic, V., Toskic, D., Preljevic, A., Kocic, M., Nedin Rankovic, G., & Damjanovic, N. (2010). Aerobic capacity as an indicator in different kinds of sports. *Bosnian journal of basic medical sciences*, 10(1), 44-48. <https://doi.org/10.17305/bjbms.2010.2734>
- Singh, L. S., Singh, S. O., Devi, O. P., Singh, W. J., & Singh, S. S. (2022). Effect of pranayama exercise on breath-holding capacity of soccer players. *International Journal of Disabilities Sports & Health Science*, 5(2), 97-105.
<https://doi.org/10.33438/ijds.1172462>
- Thompson, P. D., Arena, R., Riebe, D., & Pescatello, L. S. (2013). ACSM's new pre-participation health screening recommendations from ACSM's guidelines for exercise testing and prescription, ninth edition. *Current Sports Medicine Reports*, 12(4), 215-217.
- Singh, L. S. (2018). *Effect of Training Load*. New Delhi: Friends Publication (India).
- Islam, M. S., Rahman, M. H., Mola, D. W., Adane, A. K., & Pramanik, T. N. (2024). Nordic hamstring curls are a remedy for hamstring muscle injury: A narrative review. *International Journal of Human Movement and Sports Sciences*, 12(4), 692-698.
<https://doi.org/10.13189/saj.2024.120411>
- Shunmuganathan, D. (2018). Effect of plyometric training programme on physiological variables among adolescent school boys. *International Journal of Physiology, Nutrition and Physical Education*, 3(2), 26-28.
- Mola, D. W., & Bayisa, G. T. (2020). Effect of circuit training on selected health-related physical fitness components: The case of sport science students. *Turkish Journal of Kinesiology*, 6(4), 142-148.
<https://doi.org/10.31459/turkjin.812512>
- Chouhan, R., Misra, A., Soni, R., Joseph, A., & Umate, R. (2022). Effectiveness of Plyometrics Along With Pilates Exercises in Increasing Vertical Jump Performance Among Basketball Players. *Cureus*, 14(12), e32957.
<https://doi.org/10.7759/cureus.32957>
- Karuppasamy, G. (2018). Effect of plyometric training and circuit training on selected physical and physiological variables among male Volleyball players. *International Journal of Yoga, Physiotherapy and Physical Education*, 3(4), 26-32.
- Sivakumar, S., & Logeswaran, A. S. (2017). Effect of plyometric training on physiological variables of adolescent male tennis players. *International Journal of Physical Education, Sports and Health*, 4(3), 539-541.
- Anitha, J. (2014). Effect of plyometric training on selected physiological variables among college level volleyball players. *Experimental Biology*, 4(1), 383-386.
- Chandra, S., Sharma, A., Malhotra, N., Rizvi, M. R., & Kumari, S. (2023). Effects of Plyometric Training on the Agility, Speed, and Explosive Power of Male Collegiate Badminton Players. *Journal of lifestyle medicine*, 13(1), 52-58. <https://doi.org/10.15280/jlm.2023.13.1.52>
- Kryeziu, A. R., Iseni, A., Teodor, D. F., Croitoru, H., & Badau, D. (2023). Effect of 12 weeks of the plyometric training program model on speed and explosive strength abilities in adolescents. *Applied Sciences*, 13(5), 2776.
<https://doi.org/10.3390/app13052776>
- Anitha, D. J., Kumaravelu, D. P., Lakshmanan, D. C., & Govindasamy, K. (2018). Effect of plyometric training and circuit training on selected physical and physiological variables among male Volleyball players. *International Journal of Yoga, Physiotherapy and Physical Education*, 3(4), 26-32.
<https://doi.org/10.22271/sports.2018.v3.i4.07>
- Singh, L. S., Singh, S. O., & Thapa, S. K. (2018). Effect of Plyometric and Weight Training on Selected Physiological Variable of Football Players. *J. Adv. Sport. Phys. Edu*, 1, 75-78.
- Patir, K., Singh, S. L., Singh, S. S., & Meitei, R. (2021). Effect of plyometric training on muscular endurance of football players. *Kalyan Bharati*, 36, 182-186.

Концепція пліометричного тренування та вплив застосування даної методики на фізіологічні показники футболістів

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Реферат. Стаття: 10 с., 10 табл., 4 рис., 42 джерела.

Історія питання. Пліометричні тренування, які включають в себе комплекс вправ, що передбачають швидкісне та повторюване розтягування та скорочення м'язів, набувають дедалі більшої популярності завдяки своєму потенціалу в контексті спортивної підготовки.

Мета дослідження. Головною метою цього дослідження було вивчити принципи пліометричного тренування та оцінити, як застосування цього методу впливає на фізіологічні показники футболістів.

Матеріали та методи. До проведення дослідження було залучено 30 футболістів-чоловіків віком від 18 до 24 років, які беруть активну участь у змаганнях на національному рівні. Учасників було розподілено за методом рандомізації на дві групи: експериментальну (n = 15) та контрольну (n = 15), з кількістю 15 гравців у кожній. Обрані фізіологічні параметри з метою оцінки результатів включали аеробну продуктивність, артеріальний тиск та частоту пульсу. Рівень аеробної продуктивності вимірювали за допомогою 12-хвилинного тесту бігу/ходьби Купера, артеріальний тиск оцінювали з використанням сфігмоманометра, а частоту пульсу — за методикою вимірювання на променевій артерії. Шеститижнева програма пліометричних тренувань, що проводилася п'ять днів на тиждень, включала 60-хвилинні заняття. Експериментальна група проходила програму пліометричних тренувань, тоді як контрольна група не виконувала жодних спеціальних вправ. Показники результатів перед початком і після завершення тестування було проаналізовано статистично з використанням методів описової статистики та коваріаційного аналізу (ANCOVA). Рівень значущості був встановлений на довірчому рівні 0,05.

Результати. Отримані дані свідчать про суттєве покращення фізіологічних показників учасників експериментальної групи порівняно з контрольною групою. Впровадження пліометричної програми тренувань підтвердило свою ефективність щодо підвищення аеробної продуктивності, артеріального тиску та частоти пульсу футболістів.

Висновки. Дослідження встановило, що програма пліометричних тренувань, яка тривала шість тижнів, сприяє значному поліпшенню фізіологічних показників футболістів, зокрема аеробної продуктивності, артеріального тиску та частоти пульсу. Проведення подальших досліджень потребує вивчення довгострокових ефектів та оптимальної тривалості пліометричних тренувань, а також фізіологічних механізмів, що лежать в їх основі, з метою глибшого розуміння ефективності таких тренувань та їх застосування у спортивній підготовці.

Ключові слова: пліометричне тренування, аеробна продуктивність, артеріальний тиск, частота пульсу, футбол.

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Engaging in Short-Term Moderate-Intensity Exercise Increases Growth Hormone Levels in Individuals with Obesity

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Abstract

Objectives. This study aimed to analyze the effect of a four-week moderate-intensity exercise regimen on increasing growth hormone (GH) levels in individuals with obesity.

Materials and methods. A total of 25 female individuals aged 20-25 years, with a body mass index (BMI) of 27.50-37.00 kg/m², were involved in the study and randomly divided into two groups, namely the control group (CON; n = 12) and the moderate-intensity exercise group (MIE; n = 13). The moderate-intensity exercise regimen (treadmill exercise for 30 minutes at 60-70% of HRmax, and resistance exercise for 30 minutes at 60-70% of 1RM) was conducted 3 times per week for a period of 4 weeks. Blood samples from participants were collected pre- and post-exercise sessions, and GH levels were analyzed using the Enzyme-Linked Immunosorbent Assay method. Data analysis techniques used the paired sample t-test with a significance level of 5%.

Results. The paired sample t-test results of GH levels between the pre-exercise and post-exercise sessions in the CON group showed a change from (1291.79 ± 383.76 to 1151.53 ± 484.80 pg/mL; p = 0.694), while the MIE group demonstrated the following dynamics of change — from (1161.79 ± 133.72 to 2103.83 ± 357.09 pg/mL; p = 0.006).

Conclusions. The main findings of this study revealed that after implementing a four-week moderate-intensity exercise intervention, a significant increase in GH levels was observed in obese females.

Keywords: growth hormone, healthy lifestyle, obesity, physical exercise.

Introduction

Obesity, widely recognized as one of the greatest public health challenges of the modern era, continues to rise in prevalence worldwide (Alebnà et al., 2024). The primary factors contributing to this condition include a sedentary lifestyle and a deficit in physical activity, often associated with an unsupportive environmental factor (Aljabri, 2022). Research has shown that a lifestyle with minimal movement has a significant impact on the increase in obesity cases,

marked by a deterioration of metabolic function (Chen et al., 2024a). The lack of physical activity affects about 27.5 % of the global population, with the figure increasing to 42.3 % in high-income countries, contributing substantially to the global disease burden (Chen et al., 2024b; Guthold et al., 2018). Sedentary behavior, defined as activities with an energy expenditure of less than 1.5 metabolic equivalents (METs) during waking periods, represents the lowest level of physical activity and has been associated with increased fat mass and waist circumference, as demonstrated by significant statistical correlations (Zhang & Liu, 2024; Myers et al., 2016). Since 1990, the prevalence of obesity in adults has more than doubled, and in adolescents, it has quadrupled, with 2.5 billion adults overweight in 2022, including 890 million suffering from obesity, and more than

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390 million children and adolescents also overweight, of which 160 million are obese (WHO, 2024). The significant increase in the number of children and adolescents who are overweight and obese, along with the drastic surge in obesity cases among adults and adolescents since 1990, affirms that obesity has evolved into a serious and urgent global health issue (Pranoto et al., 2024).

Obesity is often associated with various cardiometabolic comorbidities, including metabolic syndrome, prediabetes, type 2 diabetes mellitus, atherogenic dyslipidemia, and steatotic liver disease related to metabolic dysfunction, all of which are established risk factors for coronary heart disease, heart failure, and stroke (Petersen et al., 2024). Sedentary behavior is significantly related to weight gain and substantial metabolic disturbances, including the body's inability to effectively control blood sugar and blood pressure levels, as well as a decrease in fat breakdown efficiency (Gonzalez Ramirez & Bolaños Muñoz, 2023). This unhealthy metabolic status can trigger various pathophysiological changes in the body, including blood pressure, glucose tolerance, and lipid profile (Sun et al., 2023). These metabolic disorders can also be characterized by decreased levels of Growth Hormone (GH) and an increase in body fat that occurs in obesity (Hjelholt et al., 2020). The relationship between adipose tissue and GH secretion is complex (Salvatori et al., 2015). Obesity causes hyperinsulinemia, hypoadiponectinemia, hyperleptinemia, decreased serum ghrelin, and increased free fatty acid (FFA) levels, thereby suppressing GH secretion from the pituitary (Savastano et al., 2014). GH, often referred to as the 'master hormone,' plays a key role in regulating metabolic homeostasis and has multifaceted effects on various physiological processes (Al-Samerria & Radovick, 2023).

Physical activity is considered a fundamental foundation in the management of overweight and obesity (Oppert et al., 2021). Many benefits of physical activity can be obtained from an average of 60 minutes of moderate to high-intensity physical activity every day, and exceeding this duration can yield additional health benefits (Bull et al., 2020). Research by Ashcroft et al. (2024) indicates that physiological adjustments that occur simultaneously in various tissues in response to physical activity, and the synergistic interactions between these tissues, contribute to improved cardiometabolic health. Metabolic fitness refers to the body's ability to efficiently utilize energy, regulate blood sugar levels, and maintain overall health. It is associated with a reduced risk of non-communicable diseases and mortality (Sabag et al., 2021). GH is known to play a crucial role in physiological processes such as metabolism, tissue repair, and growth, and provides direct and indirect effects on adipose tissue (Carrard et al., 2021). Furthermore, although both aerobic and resistance exercises trigger Growth Hormone (GH) responses, the relative contribution of aerobic exercise to these GH responses and actions is arguably less clear (Sabag et al., 2021). Therefore, this study aims to analyze the influence of four weeks of moderate-intensity training on increasing GH levels in individuals with obesity.

Materials and Methods

Study Participants

A total of 25 young women who were obese were recruited voluntarily to participate in this study. Participants were randomly divided into two groups: a control group

(CON; $n = 12$), and a moderate-intensity exercise group (MIE; $n = 13$). All participants received detailed information about the objectives, content, methods (exercise protocol and growth hormone function), and potential risk factors associated with the experimental design. The participants also consciously filled out and signed an Informed Consent Form. This study was conducted in accordance with the principles outlined in the Declaration of Helsinki and had received approval from the Health Research Ethics Commission (KEPK), Faculty of Medicine, Ciputra University (Indonesia) (No:103/EC/KEPK-FKUC/II/2024).

Study Design

The intervention applied in the study was moderate-intensity exercise (treadmill exercise for 30 minutes between 60-70 % of HRmax, and resistance exercise for 30 minutes between 60-70 % of 1RM), with a frequency of 3 times per week for 4 weeks. Meanwhile, the control group did not receive any form of intervention. Blood samples from participants were collected pre-exercise (before MIE) and post-exercise (after 4 weeks of MIE) from the cubital vein, amounting to 2ml, performed in the morning (08.00-10.00). GH levels were analyzed using Human Enzyme-Linked Immunosorbent Assay (ELISA) Kits (Cat.No.:E-EL-H0177; Elabscience Bionovation Inc., USA). The ELISA Kits used had been validated in previous research (Pranoto et al., 2024).

Statistical Analysis

Data analysis techniques were applied using the Shapiro-Wilk test for normality, while the paired sample t-test was used to determine differences in GH levels pre-exercise and post-exercise within each group. Meanwhile, the independent sample t-test was applied to determine differences in serum GH levels of the CON and MIE groups pre-, post-exercise, delta (pre-post), and change. The level of significance was accepted if $p \leq 0.05$.

Results

As indicated in Table 1, the values of systolic blood pressure, diastolic blood pressure, resting heart rate, oxygen saturation, body temperature, age, body weight, body height, and body mass index showed no significant differences between the two groups. Meanwhile, the results of the analysis of indicators of changes for blood pressure, resting heart rate, and body weight are presented in Table 2.

As illustrated in Fig. 1, the GH levels between pre-exercise and post-exercise in the CON group (from 1291.79 ± 383.76 to 1151.53 ± 484.80 pg/mL; $p = 0.694$) and the MIE group (from 1161.79 ± 133.72 to 2103.83 ± 357.09 pg/mL; $p = 0.006$) are presented. Figure 2 displays the GH levels between the CON and MIE groups at pre-exercise (from 1291.79 ± 383.76 to 1161.79 ± 133.72 pg/mL; $p = 0.744$), post-exercise (from 1151.53 ± 484.80 to 2103.83 ± 357.09 pg/mL; $p = 0.016$), delta (from -140.27 ± 347.62 to 942.03 ± 280.66 pg/mL; $p = 0.023$), and change (from -6.91 ± 13.83 to $80.07 \pm 22.88\%$; $p = 0.004$).

Discussion

This study aimed to analyze the effect of a four-week combined exercise regimen on increasing GH levels in

Table 1. General population description in study

Parameters	Unit	CON; n = 12	MIE; n = 13	p
Systolic blood pressure	mmHg	111.50 ± 6.36	114.54 ± 7.87	0.302
Diastolic blood pressure	mmHg	75.92 ± 5.82	79.31 ± 5.62	0.152
Resting heart rate	bpm	72.83 ± 5.48	74.39 ± 5.44	0.485
Oxygen saturation	%	97.83 ± 1.27	97.62 ± 1.19	0.662
Body temperature	°C	36.08 ± 0.33	36.12 ± 0.25	0.737
Age	ys	21.92 ± 1.31	21.62 ± 1.45	0.592
Body weight	kg	76.46 ± 9.65	76.45 ± 9.80	0.999
Body height	m	1.57 ± 0.06	1.55 ± 0.06	0.466
Body mass index	kg/m ²	30.66 ± 3.06	31.78 ± 3.24	0.384

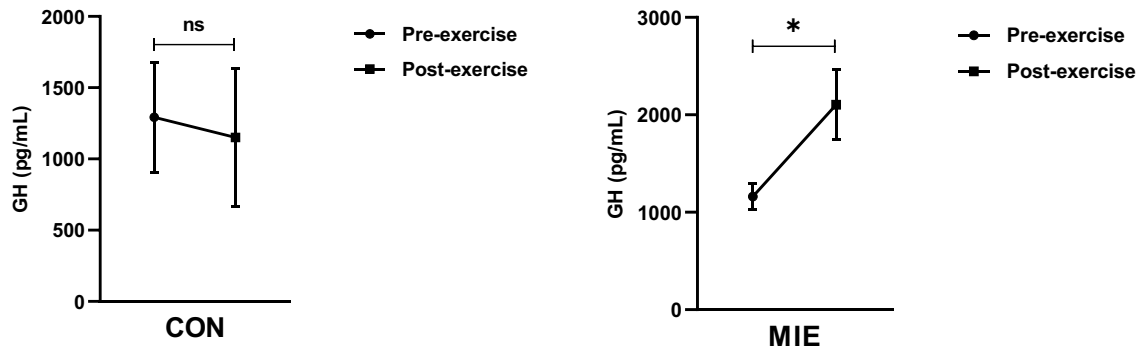


Fig. 1. Comparison of GH levels of both groups (CON and MIE) pre-exercise and post-exercise. * $p \leq 0.05$, ns: Not significant, CON: Control group, MIE: Moderate-intensity exercise group, GH: Growth hormone

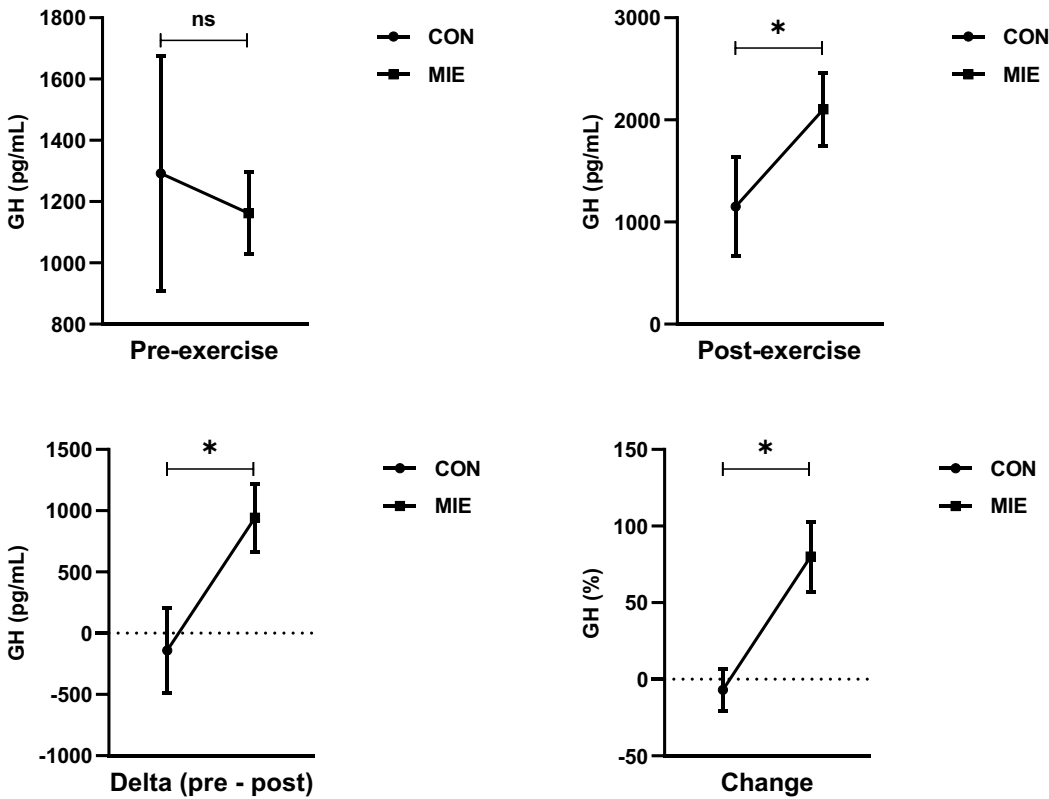


Fig. 2. Serum GH levels of CON and MIE groups pre-, post-exercise, delta (pre-post), and change. * $p \leq 0.05$, ns: Not significant, CON: Control group, MIE: Moderate-intensity exercise group, GH: Growth hormone

Table 2. Indicators of changes for blood pressure, resting heart rate, and body weight

Parameters	Unit	CON; n = 12	MIE; n = 13	p
Pre-SBP	mmHg	111.50 ± 6.36	114.54 ± 7.87	0.302
Post-SBP	mmHg	112.75 ± 4.88	111.31 ± 4.61	0.455
Changes-SBP	mmHg	1.25 ± 3.31	-3.23 ± 4.73*	0.012
Pre-DBP	mmHg	75.92 ± 5.82	79.31 ± 5.62	0.152
Post-DBP	mmHg	75.67 ± 4.96	76.23 ± 5.28	0.786
Changes-DBP	mmHg	-0.25 ± 2.83	-3.08 ± 1.26*	0.003
Pre-RHR	bpm	72.83 ± 5.48	74.39 ± 5.44	0.485
Post-RHR	bpm	72.75 ± 4.39	72.54 ± 5.29	0.915
Changes-RHR	bpm	-0.08 ± 2.71	-1.85 ± 0.80*	0.035
Pre-BW	kg	76.46 ± 9.65	76.45 ± 9.80	0.999
Post-BW	kg	76.61 ± 9.85	74.68 ± 9.32	0.622
Changes-BW	kg	0.15 ± 1.14	-1.77 ± 0.64*	0.000

Description: BW: Body weight; DBP: Diastolic blood pressure; SBP: Systolic blood pressure; RHR: Resting heart rate. *p ≤ 0.05

obese women. The findings indicate a significant increase in GH levels, affirming the potential of combined exercise as an effective intervention. This positive correlation strengthens previous findings by Sabag et al. (2021), which also documented an increase in GH post-combined exercise. Furthermore, the study by Mendonça et al. (2022) provides consistent evidence, reinforcing the view that combined exercise contributes to increased GH levels. GH has therapeutic potential due to its strong lipolytic effects and the resulting ability to reduce fat mass while maintaining lean body mass (Berryman & List, 2017).

Combined exercise plays a key role in enhancing basal metabolism and lipolysis through the induction of intense muscle contractions, as explained by Muscella et al. (2020). This mechanism is reinforced by findings from Donato et al. (2021), which show that GH-responsive neurons are widespread in various brain areas that control metabolism, with a particular focus on the hypothalamic nuclei. This response is further elaborated by Hymer & Kraemer (2023), who identified that exercise stimulates the hypothalamus to release Growth Hormone-Releasing Hormone (GHRH), which then prompts the anterior pituitary gland to release GH into circulation. Additionally, O'Neill et al. (2022) linked exercise to a reduction in blood glucose levels, which triggers GH release, demonstrating the body's adaptive mechanism to maintain glucose homeostasis.

Good metabolic health is a crucial aspect of obesity management, and physical exercise plays an important role in achieving it (Gergő Szűcs et al., 2023). Regular physical exercise can improve the metabolic profile of individuals with obesity in various ways (Liu et al., 2019). First, exercise increases insulin sensitivity, which is important for blood glucose regulation and the prevention of type 2 diabetes (Hsu et al., 2019). Second, physical activity helps reduce visceral fat, which is associated with an increased risk of cardiovascular disease (Oppert et al., 2023). Third, physical exercise promotes weight loss and the maintenance of a healthy weight, which is important for reducing the load on the musculoskeletal system and decreasing the risk of osteoarthritis (Richa et al., 2023). Fourth, physical exercise

improves body composition by increasing muscle mass, which aids in calorie burning and maintaining a healthy metabolism (Liu et al., 2019). Fifth, physical exercise also plays a role in reducing oxidative stress and inflammation, both of which contribute to the pathogenesis of obesity and its comorbidities (Gergő Szűcs et al., 2023). Therefore, integrating physical exercise into daily life is an effective strategy for improving metabolic health and reducing the risk of obesity-related diseases (Liu et al., 2019).

Combined exercise, which incorporates aerobic and anaerobic elements, has been proven effective in increasing GH levels in obese women (Davis et al., 2024). GH plays a vital role in metabolism regulation, including stimulating lipolysis and energy production (Davis et al., 2022). In individuals with obesity, increasing GH levels through combined exercise can help overcome the GH resistance often seen in obesity, contributing to decreased metabolic efficiency (Foster-Schubert et al., 2011). By increasing GH levels, combined exercise not only aids in body fat reduction but also promotes protein synthesis and muscle growth, which are important for enhancing the basal metabolic rate (Liang et al., 2021). These benefits, when combined, can result in a comprehensive improvement in metabolic health, which is crucial for long-term obesity management and quality of life enhancement (Mousa Khalafi et al., 2024). Therefore, combined exercise should be considered a valuable intervention strategy in obesity management programs for women (Davis et al., 2024). It can be concluded from this study that four weeks of combined exercise significantly increases GH levels in obese women. This study has several limitations that need to be considered. First, the study duration of only four weeks may not be sufficient to observe the long-term effects of combined exercise on GH levels. Second, the study sample was limited to obese women, so the results may not be generalizable to other populations such as men or individuals with normal weight. Third, this study did not consider other factors that may affect GH levels, such as diet, sleep quality, and stress. The findings from this study provide important clinical implications. Increasing GH levels through combined exercise could be a potential therapeutic strategy for improving the metabolic profile in obese women. This suggests that combined exercise could be integrated into obesity management programs to improve metabolic health and reduce the risk of comorbidities associated with obesity. Future research should be designed to address the limitations of this study. Longer-duration studies are needed to assess the long-term effects of combined exercise on GH levels and other health components. Additionally, studies with larger and more diverse samples will help understand the effects of combined exercise on a broader population. Further research is also needed to explore the interactions between combined exercise and factors such as diet and sleep patterns in regulating GH levels.

Conclusion

Specifically, this study found an increase in GH levels after a four-week intervention of moderate-intensity exercise in obese women. The results of this study can be taken into account in planning training programs for individuals with obesity.

Conflict of Interest

The authors declare no conflict of interest in this study.

References

- Alebna, P. L., Mehta, A., Yehya, A., daSilva-deAbreu, A., Lavie, C. J., & Carbone, S. (2024). Update on obesity, the obesity paradox, and obesity management in heart failure. *Progress in cardiovascular diseases*, 82, 34-42. <https://doi.org/10.1016/j.pcad.2024.01.003>
- Aljabri D. (2022). Associations Between Obesity, Physical Inactivity, Healthcare Capacity, and the Built Environment: Geographic Information System Analysis. *Journal of multidisciplinary healthcare*, 15, 689-704. <https://doi.org/10.2147/JMDH.S345458>
- Chen, J., Ruan, X., Fu, T., Lu, S., Gill, D., He, Z., Burgess, S., Giovannucci, E. L., Larsson, S. C., Deng, M., Yuan, S., & Li, X. (2024a). Sedentary lifestyle, physical activity, and gastrointestinal diseases: evidence from mendelian randomization analysis. *EBioMedicine*, 103, 105110. Advance online publication. <https://doi.org/10.1016/j.ebiom.2024.105110>
- Chen, S., Yang, L., Yang, Y., Shi, W., Stults-Kolehmainen, M., Yuan, Q., Wang, C., & Ye, J. (2024b). Sedentary behavior, physical activity, sleep duration and obesity risk: Mendelian randomization study. *PLoS One*, 19(3), e0300074–e0300074. <https://doi.org/10.1371/journal.pone.0300074>
- Guthold, R., Stevens, G. A., Riley, L. M., & Bull, F. C. (2018). Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1·9 million participants. *The Lancet. Global health*, 6(10), e1077–e1086. [https://doi.org/10.1016/S2214-109X\(18\)30357-7](https://doi.org/10.1016/S2214-109X(18)30357-7)
- Zhang, Y., & Liu, X. (2024). Effects of physical activity and sedentary behaviors on cardiovascular disease and the risk of all-cause mortality in overweight or obese middle-aged and older adults. *Frontiers in public health*, 12, 1302783. <https://doi.org/10.3389/fpubh.2024.1302783>
- Myers, A., Gibbons, C., Finlayson, G., & Blundell, J. (2016). Associations among sedentary and active behaviours, body fat and appetite dysregulation: investigating the myth of physical inactivity and obesity. *British Journal of Sports Medicine*, 51(21), 1540-1544. <https://doi.org/10.1136/bjsports-2015-095640>
- World Health Organization (WHO). (2024, March 1). *Obesity and Overweight*. World Health Organization. <https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight>
- Pranoto, A., Rejeki, P. S., Miftahussurur, M., Yosika, G. F., Ihsan, M., Herawati, L., Rahmanto, I., & Halim, S. (2024). Aerobic Exercise Increases Release of Growth Hormone in the Blood Circulation in Obese Women. *Retos*, 51, 726-731. <https://doi.org/10.47197/retos.v51.99944>
- Petersen, M. C., Smith, G. I., Palacios, H. H., Farabi, S. S., Yoshino, M., Yoshino, J., Cho, K., Davila-Roman, V. G., Shankaran, M., Barve, R. A., Yu, J., Stern, J. H., Patterson, B. W., Hellerstein, M. K., Shulman, G. I., Patti, G. J., & Klein, S. (2024). Cardiometabolic characteristics of people with metabolically healthy and unhealthy obesity. *Cell metabolism*, 36(4), 745-761.e5. <https://doi.org/10.1016/j.cmet.2024.03.002>
- Gonzalez Ramirez, G. & Bolaños Muñoz, L. (2023). Relationship of Sedentary Lifestyle with Obesity and Comorbidities. In: Ruiz-Tovar, J., Marc-Hernandez, A. (eds) *Physical Activity and Bariatric Surgery*. Springer, Cham. https://doi.org/10.1007/978-3-031-26614-0_1
- Sun, M., Fritz, J., Häggström, C., Bjørge, T., Nagel, G., Manjer, J., Engeland, A., Zitt, E., van Guelpen, B., Stattin, P., Ulmer, H., & Stocks, T. (2023). Metabolically (un)healthy obesity and risk of obesity-related cancers: a pooled study. *Journal of the National Cancer Institute*, 115(4), 456-467. <https://doi.org/10.1093/jnci/djad008>
- Hjelholt, A., Høgild, M., Bak, A. M., Arlien-Søborg, M. C., Bæk, A., Jessen, N., Richelsen, B., Pedersen, S. B., Møller, N., & Lunde Jørgensen, J. O. (2020). Growth Hormone and Obesity. *Endocrinology and metabolism clinics of North America*, 49(2), 239-250. <https://doi.org/10.1016/j.ecl.2020.02.009>
- Salvatori R. (2015). Growth hormone deficiency in patients with obesity. *Endocrine*, 49(2), 304-306. <https://doi.org/10.1007/s12020-015-0571-4>
- Savastano, S., Di Somma, C., Barrea, L., & Colao, A. (2014). The complex relationship between obesity and the somatotropic axis: The long and winding road. *Growth Hormone & IGF Research*, 24(6), 221–226. <https://doi.org/10.1016/j.gthr.2014.09.002>
- Al-Samerria, S., & Radovick, S. (2023). Exploring the Therapeutic Potential of Targeting GH and IGF-1 in the Management of Obesity: Insights from the Interplay between These Hormones and Metabolism. *International journal of molecular sciences*, 24(11), 9556. <https://doi.org/10.3390/ijms24119556>
- Oppert, J., Bellicha, A., Van Baak, M. A., Battista, F., Beaulieu, K., Blundell, J. E., Carraça, E. V., Encantado, J., Ermolao, A., Pramono, A., Farpour-Lambert, N., Woodward, E., Dicker, D., & Busetto, L. (2021). Exercise training in the management of overweight and obesity in adults: Synthesis of the evidence and recommendations from the European Association for the Study of Obesity Physical Activity Working Group. *Obesity Reviews*, 22(S4), e13273. <https://doi.org/10.1111/obr.13273>
- Bull, F. C., Al-Ansari, S. S., Biddle, S., Borodulin, K., Buman, M. P., Cardon, G., Carty, C., Chaput, J. P., Chastin, S., Chou, R., Dempsey, P. C., DiPietro, L., Ekelund, U., Firth, J., Friedenreich, C. M., Garcia, L., Gichu, M., Jago, R., Katzmarzyk, P. T., Lambert, E., ... Willumsen, J. F. (2020). World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *British journal of sports medicine*, 54(24), 1451-1462. <https://doi.org/10.1136/bjsports-2020-102955>
- Ashcroft, S. P., Stocks, B., Egan, B., & Zierath, J. R. (2024). Exercise induces tissue-specific adaptations to enhance cardiometabolic health. *Cell metabolism*, 36(2), 278-300. <https://doi.org/10.1016/j.cmet.2023.12.008>
- Sabag, A., Chang, D., & Johnson, N. A. (2021). Growth Hormone as a Potential Mediator of Aerobic Exercise-Induced Reductions in Visceral Adipose Tissue. *Frontiers in physiology*, 12, 623570. <https://doi.org/10.3389/fphys.2021.623570>
- Carrard, J., Guerini, C., Appenzeller-Herzog, C., Infanger, D., Karsten Königstein, Lukas Streese, Hinrichs, T., Hanssen, H., Gallart-Ayala, H., Julijana Ivanisevic, & Arno Schmidt-Trucksäss. (2021). The Metabolic Signature of Cardiorespiratory Fitness: A Systematic Review. *Sports Medicine*, 52(3), 527-546. <https://doi.org/10.1007/s40279-021-01590-y>
- Mendonça, F. R., Ferreira de Faria, W., Marcio da Silva, J., Massuto, R. B., Castilho Dos Santos, G., Correa, R. C., Ferreira Dos Santos, C., Sasaki, J. E., & Neto, A. S. (2022). Effects of aerobic exercise combined with resistance training on health-related physical fitness in adolescents: A randomized controlled trial. *Journal of exercise science and fitness*, 20(2), 182-189. <https://doi.org/10.1016/j.jesf.2022.03.002>

- Berryman, D., & List, E. (2017). Growth Hormone's Effect on Adipose Tissue: Quality versus Quantity. *International Journal of Molecular Sciences*, 18(8), 1621. <https://doi.org/10.3390/ijms18081621>
- Muscella, A., Stefano, E., Lunetti, P., Capobianco, L., & Marsigliante, S. (2020). The Regulation of Fat Metabolism During Aerobic Exercise. *Biomolecules*, 10(12), 1699. <https://doi.org/10.3390/biom10121699>
- Donato, J., Jr, Wasinski, F., Furigo, I. C., Metzger, M., & Frazão, R. (2021). Central Regulation of Metabolism by Growth Hormone. *Cells*, 10(1), 129. <https://doi.org/10.3390/cells10010129>
- Hymer, W. C., & Kraemer, W. J. (2023). Resistance exercise stress: theoretical mechanisms for growth hormone processing and release from the anterior pituitary somatotroph. *European Journal of Applied Physiology*, 123(9), 1867-1878. <https://doi.org/10.1007/s00421-023-05263-8>
- O'Neill, C. C., Locke, E. J., Sipf, D. A., Thompson, J. H., Drebuschenko, E. K., Berger, N. S., Segich, B. S., & Kolwicz, S. C., Jr (2022). The Effects of Exercise Training on Glucose Homeostasis and Muscle Metabolism in Type 1 Diabetic Female Mice. *Metabolites*, 12(10), 948. <https://doi.org/10.3390/metabo12100948>
- Gergő Szűcs, Márton Pipicz, Szabó, M., Tamás Csont, László Török, & Csonka, C. (2023). Effect of Eccentric Exercise on Metabolic Health in Diabetes and Obesity. *Sports Medicine - Open*, 9(1). <https://doi.org/10.1186/s40798-023-00596-2>
- Liu, S., Niu, Y., & Fu, L. (2019). Metabolic Adaptations to Exercise Training. *Journal of Science in Sport and Exercise*, 2(1), 1-6. <https://doi.org/10.1007/s42978-019-0018-3>
- Hsu, K.-J., Liao, C.-D., Tsai, M.-W., & Chen, C.-N. (2019). Effects of Exercise and Nutritional Intervention on Body Composition, Metabolic Health, and Physical Performance in Adults with Sarcopenic Obesity: A Meta-Analysis. *Nutrients*, 11(9). <https://doi.org/10.3390/nu11092163>
- Oppert, J.-M., Ciangura, C., & Bellicha, A. (2023). Physical activity and exercise for weight loss and maintenance in people living with obesity. *Reviews in Endocrine and Metabolic Disorders*, 24. <https://doi.org/10.1007/s11154-023-09805-5>
- Rai, R. H., Singh, R. B., Mehta, V., Sakshi, Asif, M., Goyal, K., Balodhi, A., Manglik, P., Sharma, A., & Chahal, A. (2023). Impact of exercise training duration on obesity and cardiometabolic biomarkers: A systematic review. *Journal of Diabetes & Metabolic Disorders*, 22(1), 155-174. <https://doi.org/10.1007/s40200-023-01219-z>
- Davis, M. E., Blake, C., & O'Donoghue, G. (2024). Comparison of time-matched aerobic, resistance or combined exercise training in women living with obesity: The EXOFFIT study. *Obesity science & practice*, 10(2), e749. <https://doi.org/10.1002/osp4.749>
- Davis, M. E., Blake, C., Cunningham, C., Carson, B. P., & O'Donoghue, G. (2022). Comparison of time-matched aerobic, resistance or combined exercise training in women living with obesity: a protocol for a pilot randomised controlled trial—the EXOFFIT (Exercise for Obesity in Females to increase Fitness) study. *Pilot and Feasibility Studies*, 8(1). <https://doi.org/10.1186/s40814-022-01003-5>
- Foster-Schubert, K. E., Alfano, C. M., Duggan, C. R., Xiao, L., Campbell, K. L., Kong, A., Bain, C. E., Wang, C.-Y., Blackburn, G. L., & McTiernan, A. (2011). Effect of Diet and Exercise, Alone or Combined, on Weight and Body Composition in Overweight-to-Obese Postmenopausal Women. *Obesity*, 20(8), 1628-1638. <https://doi.org/10.1038/oby.2011.76>
- Liang, M., Pan, Y., Zhong, T., Zeng, Y., & Cheng, A. S.K. (2021). Effects of aerobic, resistance, and combined exercise on metabolic syndrome parameters and cardiovascular risk factors: a systematic review and network meta-analysis. *Reviews in Cardiovascular Medicine*, 22(4), 1523. <https://doi.org/10.31083/j.rcm2204156>
- Mousa Khalafi, Symonds, M., Aref Habibi Maleki, Mohammad Hossein Sakhaei, Mahsa Ehsanifar, & Rosenkranz, S. K. (2024). Combined versus independent effects of exercise training and intermittent fasting on body composition and cardiometabolic health in adults: a systematic review and meta-analysis. *Nutrition Journal*, 23(1). <https://doi.org/10.1186/s12937-023-00909-x>

Заняття короткотривалими фізичними вправами помірної інтенсивності підвищують рівень гормону росту в осіб з ожирінням

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів
Реферат. Стаття: 7 с., 2 табл., 2 рис., 37 джерел.

Мета дослідження. Мета цього дослідження полягала в аналізі впливу застосування чотириразового режиму фізичних вправ помірної інтенсивності на підвищення рівня гормону росту (ГР) в осіб з ожирінням.

Матеріали та методи. У дослідженні взяли участь 25 осіб жіночої статі віком 20-25 років з індексом маси тіла (ІМТ) 27,50-37,00 кг/м², які були розподілені за методом рандомізації на дві групи: контрольну (КОН; n = 12) та групу тренувань помірної інтенсивності (ТПІ; n = 13). Режим фізичних вправ помірної інтенсивності (тренування на біговій доріжці протягом 30 хвилин на рівні 60-70% від максимальної частоти серцевих скорочень (ЧСС макс.) та вправи з опором протягом 30 хвилин на рівні 60-70% від показника максимуму одного повторення або 1ПМ — вказує на максимальну вагу, яку можна підняти з максимальним зусиллям за одне повторення) проводили 3 рази на тиждень впродовж 4-тижневого періоду. В учасників дослідження відбирали зразки крові перед початком і після закінчення тренувань, а рівень гормону росту визначали за допомогою методу ферментного імуносорбентного аналізу. Під час аналізу даних використовувався t-критерій для парних вибірок з рівнем значущості 5%.

Результати. Результати t-критерію для парних вибірок рівнів гормону росту між сеансами перед та після проведення тренування в контрольній групі показали змінення з (1291,79 ± 383,76 до 1151,53 ± 484,80 пг/мл; p = 0,694), в той час як група тренувань помірної інтенсивності продемонструвала таку динаміку змінення — з (1161,79 ± 133,72 до 2103,83 ± 357,09 пг/мл; p = 0,006).

Висновки. Згідно з ключовими висновками цього дослідження встановлено, що після впровадження інтервенції у вигляді комплексу фізичних вправ помірної інтенсивності впродовж чотирьох тижнів у жінок з ожирінням спостерігалось значне підвищення рівня гормону росту.

Ключові слова: гормон росту, здоровий спосіб життя, ожиріння, фізичні вправи.

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Retraction Note

The Editors have retracted the following article:

Muhammad, Siantoro, G., Subagio, I., Yosika, G. F., Phanpheng, Y., Pramono, B. A., Kusuma, I. D. M. A. W., & Pranoto, A. (2024). Engaging in Short-Term Moderate-Intensity Exercise Increases Growth Hormone Levels in Individuals with Obesity. *Physical Education Theory and Methodology*, 24(4), 619-625. <https://doi.org/10.17309/tmfv.2024.4.14>

The Editors retract this article due to identified errors in citation. The authors did not consent to the retraction of the article.

We have been informed in our decision-making by our policy on publishing ethics and COPE guidelines.

The retracted article will remain online to maintain the scholarly record, but it will be digitally watermarked on each page as "Retracted".



The Influence of School Pathologies on the Feeling of Pedagogical Incompetence in Teaching Inclusive Physical Education

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Abstract

Background. Inclusion requires a variety of pedagogical skills for the successful learning and well-being of all children. Teachers face daily challenges in meeting the needs of students while ensuring quality learning and facilitating personal development, regardless of their situation.

Objectives. The study aimed to clarify the activities of students who don't participate in physical education and how it affects teachers' sense of pedagogical competence (TSPC) in this area, by examining the effect of other potential factors and investigating the interactions with their perceptions of their students' participation in pedagogical activities.

Materials and methods. The research approach used to perform this study was based on a survey of 918 pathological students (5.85 %) and 298 physical education teachers (including 74 females, all over 21 years old) in public schools. The questionnaire consisted of three parts: socio-demographic and student engagement questions, TSPC towards teachers' inclusive practice, and their perceptions related to students' participation in PES educational activities. The items in the last two parts were represented in Likert 5-scale format.

Results. The results showed that boys (62.66 %) with pathologies were more physically involved, and this trend was particularly marked in rural areas (69.40 %). Only a minority of students chose alternative activities during class (14.91 % chose another subject, 8.40 % went to the library). Socio-professional factors influence perceptions and TSPC regarding the participation of students with pathologies in physical activities and other learning tasks, varying according to each type of pathology. TSPC has a highly significant effect on perceptions of students' inclusion in motor, organizational and observational tasks ($p = 0.000$). Finally, when teachers feel pedagogically incompetent, this is reflected in negative attitudes and perceptions toward inclusion.

Conclusions. According to the findings of this study, it has been revealed that boys with disabilities in rural areas are more physically active than girls. Furthermore, the study indicates that teachers' perceptions and sense of pedagogical competence have a strong influence on the inclusion of students with disabilities.

Keywords: school inclusion, learning task, inclusive physical education, teachers' perception, teachers' pedagogical competence, inclusive practices.

Introduction

In 2023 in the annual report on the statistical collection of education in Morocco found that the regular schooling of children with disabilities (SH) is 4.27 % ($n = 37911$), of which 0.85 % motor, 0.23 % visual, 1.35 % mental, 0.42 % auditory, 0.54 % autism and 1.39 % learning disabilities, including 0.16 % schooled in integrated classes (Direction de la stratégie des statistiques et de la Planification, 2023). What's more, 436,000 students with SH attend school with their peers in France. While inclusive education requires theoretical validation as well as methodological and practical

expertise to promote the inclusion of students in pedagogical activities as well as in teaching-learning processes (Direction des Curricula, 2019a). As well as ensuring equity in terms of school fairness, quality of learning and overall harmonious promotion of students' potential (physical, emotional, moral and cognitive) (CSEFRS, 2015). The complexity of its successful implementation is often overlooked in curricular guidelines and guides, which is why in 2019 Morocco has conceptualized several guides to inclusive education for school directors (Direction des Curricula, 2019b), teachers (Direction des Curricula, 2019a), associations and families (Direction des Curricula, 2019c), based on the inclusive education reference framework (Direction des Curricula, 2019d). These efforts are part of a framework to strengthen the inclusive professional skills of the various actors and

stakeholders to ensure mainstream education and high performance school inclusion for all students (Myklebust, 2006), regardless of their abilities or disabilities (Direction des Curricula, 2019a). While other organizations have focused on adapted and inclusive physical activity (Kelly, 1995; National Center on Health Physical Activity and Disability, 2017), as well as adaptations and support for students to participate fully in physical and sports education (PSE) sessions (American Association of Adapted Sports Programs (AAASP), 2019).

This subject represents an important pillar of education and the transmission of values, and allows the acquisition of various personal qualities, such as autonomy, cooperation, personal and social responsibility... through the participation in integrative physical activities with their peers (André et al., 2011; Mamak et al., 2020; Viciano et al., 2017). On the other hand, it improves performance and academic achievement (Donnelly et al., 2009; Sallis et al., 1999), and has a positive impact on the health of the practitioner, while those who have a high level of PA feel more athletic and have a good physical condition, quality of life and self-image (Groff et al., 2009; Sallis et al., 1999; Saskia et al., 2018). Consequently, adaptations and diversifications of school inclusion are recommended according to the pathology or disability; these adaptations are essential if all students are to participate fully and safely. Teaching practice in PES with these students requires a professional, systematic and practical rehabilitation of inclusive education and its application procedures to promote inclusive teaching at the levels of design, implementation, orientation, follow-up and evaluation (Direction des Curricula, 2019c). Its success depends on the teacher's contribution to the creation of a motivational climate that leads to the social and educational integration of the student in a differentiated group (Wilhelmsen et al., 2019). The pursuit of equal educational opportunities between these students and their peers does not guarantee their sense of inclusion (King, 2013), but the physical involvement that fosters a sense of educational and social inclusion. In neutral, positive interactions between students and their teachers are the basis for creating an inclusive learning environment for all (Klavina et al., 2008; Seymour et al., 2009; Spencer-Cavaliere & Watkinson, 2010). Creating a climate based on mastery and/or autonomy rather than achievement reflects a motivational pedagogy that is socially and pedagogically inclusive (Wilhelmsen et al., 2019).

In PES, teachers are often confronted with great diversity among their students, a situation that makes their teaching practice more complex, especially when they work with groups of students suffering from pathologies. This diversity represents a major challenge that they are not always able to cope with satisfactorily, unlike in the associative environment where the practice often consists of grouping pupils according to their performance in relatively homogeneous categories. Indeed, in addition to the diversity of students, teachers have to juggle a variety of knowledge to teach, tasks and contexts, as well as different performance standards. The goal of inclusion is to provide all students, regardless of their needs, with equitable educational opportunities of high pedagogical quality. In this context, physical education teachers play a critical role in creating a learning environment in which each student can fully participate, develop motor and social skills, and thrive. They

promote enjoyment of physical activity, manage time and space constraints, establish a balance of authority, create a climate conducive to learning, attend to the individual needs of each student while encouraging interaction among them, and adapt to the unexpected while respecting the established program. This context requires an understanding of these complex dynamics. First, to analyze the alternatives for the participation of students with pathologies in physical education. Second, to measure the impact of pathologies on teachers' sense of pedagogical competence (TSPC). Then, the effect of pathologies on their perceptions of student participation in learning activities in PE. In neutral, to investigate the nature of the relationship between TSPC and their perceptions. Finally, to investigate other factors that modulate this relationship. The objective of this thesis is to determine what students who don't participate in physical education classes do, and how the type of pathology affects TSPC in relation to inclusive physical education, taking into account other factors that may influence this relationship, and explore their interaction with their perceptions of their students' involvement in educational activities, for the relevance of health promotion and the inclusion of students with illnesses and disabilities in physical education classes.

Materials and Methods

Study Participants

Data were collected through online questionnaires administered to physical education teachers in public schools in the Beni Mellal-Khénifra region. To ensure data integrity, participation was voluntary and responses were anonymous. The selection of medical files was based on the inclusion criteria, which included children between 13 and 18 years of age, enrolled in public secondary schools, with pathologies confirmed by a physician. A total of 918 (5.85%) students pathological case conformed during the diagnosis of 93870 medical records, of them mis 59.80% (n = 549) who are engaged, while 40.20% (n = 369) who do not feel engaged to physical education sessions. These students are enrolled with 298 physical education teachers working in public schools in the territory of the Beni Mellal-Khenifra Regional Directorate of the Ministry of National Education, Preschool and Sports. First of all, it's noteworthy that the 20-29 age group (66.78%) is the most represented among all the participants. The latter is more populated by men (75.45%). The majority has less than 5 years of experience (66.78%). This trend is slightly more pronounced among women (63.51%), with a predominance of teaching in urban areas (80.87%). In neutral, it is relatively balanced between the sexes, with an almost equal distribution found between college secondary (38.26%) and qualifying secondary (61.74%), although slightly more teachers work in qualifying secondary. Finally, the majority of them have a Diplôme de Centres Régionaux des Métiers d'Education et de Formation (CRMEF) (42.62%).

Measuring Instrument

The validation of the questionnaire used has been carried out in four different stages, including an in-depth analysis of international references and school health registries, followed by the design of specific items and the validation

of these items by experts in school medicine and adapted sports. We carried out a meticulous analysis of international references on the classification of health anomalies and school inclusion. In particular, we studied two major axes: the International Classification of Functioning, Disability and Health (World Health Organization, 2012) and the Parasporic Classification of Disability (Comité International Paralympique, 2016). We then carried out an analysis of the school health registers to identify the most common diseases and their status of inclusion or exclusion in physical education. We then began to design questionnaire items focusing on teachers' sense of pedagogical competence (TSPC) and their perception of the inclusion of school pathologies in the 3 types of learning tasks, such as motor skills development (motor tasks), organization and group observation. Based on the most programmed cycles in this geographical region, the pedagogical guidelines (Direction des Curricula et de Vie Scolaire, 2007), and the list of Paralympic sports updated during the Tokyo Games (Comité International Paralympique, 2020). Finally, the axis dealing with the classification of health anomalies was subjected to the evaluation of five experts in school medicine, resulting in a classification comprising 12 main pathology groups. Similarly, the second axis, dedicated to modeling inclusive educational activities, was validated by a group of experts including specialists in para-sport and physical education. The validated instrument was then administered online to PES teachers.

Statistical Analysis

The results obtained were analyzed using SPSS software version 27.0.1.0. First, a descriptive analysis was performed according to gender, including the three types of learning tasks for each pathology group. Next, a χ^2 test was calculated to measure differences between groups according to socio-professional factors. Descriptive analyses of the means and standard deviations of their perceptions were followed by an ANOVA I variance test to assess the effect of socio-professional factors on the variation in their perceptions. Finally, an ANOVA I test was performed to assess the impact of teachers' sense of pedagogical competence (TSPC) on their perceptions of the inclusion of students with pathologies in their pedagogical activities.

Results

This section presents four lines of analysis. First, we present descriptive data on the frequency and percentage of students with diagnosed disorders who participated and did not participate in physical activity at school, and then the difference between them as a function of demographic factors. Then we'll evaluate the difference in terms of socio-professional factors. We then analyze their perception of the physical involvement of pathologies in learning tasks, while measuring the impact of socio-professional factors. Finally, we measure the impact of the TSPC on their perceptions.

Analysis of the distribution of students with pathologies participating in PE classes

The highest prevalence of diseases is observed in the male population (37.47%; 3.66‰) than in the female

population (22.33%; 2.18‰). However, boys have higher rates, as metabolic abnormalities are more common in boys (6.21%; 0.61‰) than in girls (2.94%; 0.29‰), and cardiovascular abnormalities are also more common in boys (6.21%; 0.61‰) than in girls (1.53%; 0.15‰). Among students aged 12 to 15, the overall prevalence is 52.28% (3.06‰). While those aged 16 to 18 show a slightly lower prevalence of 47.72% (2.79‰). On the other hand, the rate is higher in rural areas (69.40%; 4.06‰) than in urban areas (30.60%; 1.79‰). This variability is significantly different ($p < 0.05$) according to sex, age and zone in most of the pathology groups.

Disengaged student breakdown by sex, age and region

It should be noted that, regardless of gender, age and region, there is no significant difference between alternative activities. Of course, 27.65% (2.70‰) of the confirmed population didn't declare what they do, in contrast to 5.99% (0.59‰) who return to another subject, 3.42% (0.33‰) who return to the school library and 3.14% (0.31‰) who absent themselves instead of benefiting from their physical education. Boys, on the other hand, are more disengaged in physical education with a prevalence of 77.30%. This trend is associated with the age category 16-18 years (60.28%) and with the urban area (63.12%), which means that students aged 16-18 years living in the urban area are more disengaged.

Differences in TSPC regarding their inclusive teaching practices in physical education

Table 3 shows the difference in teachers' sense of competence (TSPC) towards the inclusion of students with pathologies in educational activities in PES as a function of socio-professional factors. Men felt more competent to adapt motor tasks ($n = 176$; 59.06%), organizational tasks ($n = 146$; 49.13%) and observational tasks ($n = 165$; 55.37%) than women (respectively $n = 36$; 21.25%, $n = 56$; 18.90%, $n = 60$; 20.27%). On the other hand, feelings of incompetence predominated in most cases for both sexes and varied according to each pathology group. On the other hand, there is a significant difference ($p < 0.05$) between the experience of the physical education teachers, the experience with the pathological students, the basic training, the zone and the cycle of belonging, while there is no difference between the sex and the age ($p > 0.05$).

Analysis of teachers' perceptions of the participation of students with pathologies in physical activities and learning tasks

Table 4 shows the influence of socio-professional factors on teachers' perceptions of the involvement of students with pathologies in learning tasks in PES. These results show that perceptions of physical participation in learning tasks vary according to the type of disability and the sport activity practiced. On average, teachers were more cautious about motor impairments such as hemiplegic paralysis, lower amputation, osteoarticular anomalies and upper amputation (1.96 ± 0.82 , 2.58 ± 1.10 , 2.73 ± 1.15 , 2.77 ± 1.23 , respectively) and cardiovascular disorders (2.74 ± 1.20). However, neither

Table 1. Distribution and difference of diagnosed disorders related to participation in PE by gender

Pathologies	Sex						χ^2	Total	
	Female			Male				n (%) Con Confirmed	%o/N Diagnosed
	n (%) relatif	%/918 Confirmed	%o/N Diagnosed	n (%) relatif	%/918 Confirmed	%o/N Diagnosed			
Upper amputation	15 (53.57 %)	1.63 %	0.16 ‰	13 (46.43 %)	1.42 %	0.14 ‰	0.013	28 (5.10 %)	3.05 %
Lower amputation	32 (74.42 %)	3.49 %	0.34 ‰	11 (25.58 %)	1.20 %	0.12 ‰	0.000	43 (7.83 %)	4.68 %
Hemiplegic paralysis	17 (60.71 %)	1.85 %	0.18 ‰	11 (39.29 %)	1.20 %	0.12 ‰	0.000	28 (5.10 %)	3.05 %
Osteoarticular	25 (43.86 %)	2.72 %	0.27 ‰	32 (56.14 %)	3.49 %	0.34 ‰	0.039	57 (10.38 %)	6.21 %
Psychological	20 (35.71 %)	2.18 %	0.21 ‰	36 (64.29 %)	3.92 %	0.38 ‰	NS	56 (10.20 %)	6.10 %
Intellectual	15 (53.57 %)	1.63 %	0.16 ‰	13 (46.43 %)	1.42 %	0.14 ‰	0.013	28 (5.10 %)	3.05 %
Visual	18 (42.86 %)	1.96 %	0.19 ‰	24 (57.14 %)	2.61 %	0.26 ‰	NS	42 (7.65 %)	4.58 %
Auditory	2 (14.29 %)	0.22 %	0.02 ‰	12 (85.71 %)	1.31 %	0.13 ‰	NS	14 (2.55 %)	1.53 %
Metabolic	27 (32.14 %)	2.94 %	0.29 ‰	57 (67.86 %)	6.21 %	0.61 ‰	NS	84 (15.30 %)	9.15 %
Respiratory	12 (21.43 %)	1.31 %	0.13 ‰	44 (78.57 %)	4.79 %	0.47 ‰	0.021	56 (10.20 %)	6.10 %
Cardiovascular	14 (19.72 %)	1.53 %	0.15 ‰	57 (80.28 %)	6.21 %	0.61 ‰	0.001	71 (12.93 %)	7.73 %
Immune	8 (19.05 %)	0.87 %	0.09 ‰	34 (80.95 %)	3.70 %	0.36 ‰	0.024	42 (7.65 %)	4.58 %
Total	205 (37.34 %)	22.33 %	2.18 ‰	344 (62.66 %)	37.47 %	3.66 ‰	-	549 (100 %)	59.80 %

All values are expressed as frequencies (percentages), NS. Not significant, significance $p < 0.05$.

Table 2. Percentage of Students Not Participating in PE, by Gender

Pathologies	Sex						χ^2	Total		
	Female			Male				n (%) Disengaged	n (%) Con Confirmed	%o/N Diagnosed
	n (%) relatif	%/918 Confirmed	%o/N Diagnosed	n (%) relatif	%/918 Confirmed	%o/N Diagnosed				
Undeclared	58 (22.66 %)	15.60 %	0.61 ‰	196 (77.27 %)	53.19 %	2.09 ‰	NS	254 (68.83 %)	27.65 %	2.70 ‰
Absent	5 (18.07 %)	1.42 %	0.06 ‰	24 (81.17 %)	6.38 %	0.25 ‰	NS	29 (7.86 %)	3.14 %	0.31 ‰
Go to another subject	13 (23.82 %)	3.55 %	0.14 ‰	42 (76.15 %)	11.35 %	0.45 ‰	NS	55 (14.91 %)	5.99 %	0.59 ‰
Return to library	8 (25.35 %)	2.13 %	0.08 ‰	24 (75.94 %)	6.38 %	0.25 ‰	NS	31 (8.40 %)	3.42 %	0.33 ‰
Total	84 (22.70 %)		0.89 ‰	285 (77.30 %)		3.04 ‰	-	369 (100 %)	40.20 %	3.93 ‰

All values are expressed as frequencies (%), NS. Not significant, significance $p < 0.05$.

Table 3. Differences in TSPC with regard to the inclusion of students with pathologies in physical education classes according to socio-professional factors

Variables	Sex	Age	Experience in PE	Experience with disabilities	Basic training	Work area	Work cycle
TSPC – Inclusion in motor tasks	NS	NS	0.000	0.000	0.000	0.000	0.000
TSPC – Inclusion in organizational tasks	NS	NS	0.000	0.000	0.000	0.000	0.000
TSPC – Inclusion in observation tasks	NS	NS	0.000	0.000	0.000	0.000	0.000

TSPC. Teachers' sense of pedagogical competence, NS. Not Significant, χ^2 p-value < 0.05

Table 4. The effect of socio-professional factors on teachers' perceptions of the participation of students with pathologies in PE activities

Variables	Mean $\pm$ SD	Experience in PE	Experience with disabilities	Basic training	Work area	Work cycle
Teachers' perceptions - Inclusion in motor tasks	2.990 $\pm$ 0.945	0.000	0.000	0.000	0.000	NS
Teachers' perceptions - Inclusion in organizational tasks	3.376 $\pm$ 1.225	0.000	0.002	0.000	0.001	NS
Teachers' perceptions - Inclusion in observation tasks	3.740 $\pm$ 1.348	0.002	NS	0.000	0.001	0.029

SD. Standard Deviation, NS. Not Significant, ANOVA I p-value < 0.05

sex nor age had any influence. On the other hand, area, cycle and teaching experience or experience with a student with a pathological condition in physical education had an influence on the teachers' perception of the participation of students with physical activity abnormalities in organizational and observation tasks in physical education ($p < 0.05$).

Impact of teachers' sense of pedagogical competence on their perception of the participation of students with pathologies in PE

This table presents the results of the influence of teachers' sense of competence on their perception of students' involvement in different learning activities in PES. Their data are presented as overall means with standard deviation ($\pm$ SD). On average, these teachers have more positive perceptions in relation to the inclusion of students in motor tasks ($m = 2.990$), in those of organization ($m = 3.376$) and in those of observation ($m = 3.740$). However, their feelings of competence had a significant effect ($p < 0.05$) on their perceptions of students' involvement in motor, organization, and observation tasks.

Table 5. Effect of TSPC on their perceptions of learning tasks

Variables	N	Mean $\pm$ SD	ANOVA I
TSPC – Teachers' perceptions of including students in motor tasks	298	2.990 $\pm$ 0.945	0.000
TSPC – Teachers' perceptions of students' inclusion in organizational tasks	298	3.376 $\pm$ 1.225	0.000
TSPC – Teachers' perceptions of student inclusion in observation tasks	298	3.740 $\pm$ 1.348	0.000

Discussion

This study found that boys with pathologies are more physically active than girls (37.34 %), with this trend slightly balanced between age groups. However, it is more pronounced in rural areas (69.40 %), indicating that non-urban students participate more in physical activities. Research has shown that urban girls perform better physically than rural girls, while rural boys perform better than urban boys (Hadjrioua et al., 2020). Conversely, the commitment of students in urban areas is less significant, as they are situated in close proximity to their educational institutions, which encourages a sedentary lifestyle. Conversely, those who have a relatively slow commute and walk to school will be more likely to engage in daily physical activity. There is a correlation between the amount of time spent outside the home by the child and an increase in physical activity (Larouche et al., 2019). Conversely, a significant barrier to physical activity is the practice of parents transporting their children to school (Larouche et al., 2019). Conversely, the high rate of undeclared disengagement (68.83 %) is particularly noteworthy, as it suggests the need for a more in-depth exploration of the reasons for under-reporting participation. Moreover, the finding that only a minority of students select alternative

activities during lessons (14.91 % choose another subject, 8.40 % go to the library) indicates that there is potential to promote more active and engaged participation in physical education. Researchers have demonstrated that some students engage in conversation with one another during the session, or engage in other forms of non-productive behavior with the material, while others exhibit a lack of responsiveness to the teacher's instructions and adopt a passive attitude (Potvin & Lacroix, 2009). Nevertheless, the findings indicate that students with medical conditions are also engaged. One study indicated that individuals with cerebral palsy were the most involved, with the exception of certain gymnastics activities (Blinde & McCallister, 2015). Another study found that there is a notable discrepancy in participation in inclusive school sports physical activities (Ben Rakaa et al., 2024), despite the diversity of disability types in PE. Research has demonstrated that all high achievers in the class engage in PE, which aligns with our findings. Additionally, a strong correlation ($r = 0.76$) was observed between self-efficacy and the capacity to participate in an uninhibited manner, while the ability to be physically involved in the activity was observed during lessons (Bertills et al., 2017). The probability of engaging in a given activity is greater when it is a regular occurrence. Consequently, disabled students' motor engagement time (MET) in activities is demonstrably lower than that of their non-disabled peers (Eriksson et al., 2007).

The results of this study were found to be contradictory to those of previous research, which had concluded that there was a significant difference in teachers' sense of self-efficacy according to gender. However, in this study, TSPC did not differ between gender or age. In addition, several other socio-professional factors were found to affect this feeling, including experience in teaching PE, specific experience with those suffering from a disability or illness, basic training for teaching PE, area and cycle of belonging ($p < 0.05$). However, it should be noted that this distribution changes according to each pathology group. This elucidates why pedagogical incompetence can be ascribed to oneself, for example, due to a dearth of experience, or to an external factor, such as inadequate initial training, or difficulties in managing the situation due to limited resources (material or human) (Martineau & Presseau, 2003). In recent years, the complexity of teaching has increased significantly, primarily due to the expanded responsibilities of teachers and the diversification of the school population. This situation presents teachers with unprecedented challenges that often exceed the scope of their university training (Robert & Tondreau, 1997), as evidenced by the findings of our study. Conversely, research demonstrated that educators exhibited a generally favorable attitude toward the inclusion of children with special needs. However, male educators demonstrated a more positive perception of the pedagogical effectiveness of these children than their female counterparts. Furthermore, the more efficacious the teachers, the more favorable their attitudes toward educational inclusion (Dukmak et al., 2019).

The extent of physical involvement permitted for students with pathologies varies according to the type of activity in question. The study concluded that teachers are more reluctant to include students with motor deficiencies such as paralysis, amputations, osteoarticular diseases, and other cardiovascular diseases. Similarly, the study demonstrated that these educators exhibit a reluctance

to engage their students in motor tasks, a moderate level of reluctance in organization tasks, and a high level of reluctance in observation tasks. This finding provides justification for the hypothesis that those with a higher degree of involvement will have motor tasks, while those with a lower degree of involvement will have organization and observation tasks (Ben Rakaa et al., 2024). The findings of previous studies indicate that these students typically assume the roles of referee, judge, and observer. However, the exclusion of students from participation in sports is not typically due to a lack of interest or an attempt to eliminate certain activities (Blinde & McCallister, 2015). Instead, it is often due to the incompatibility of tasks and circumstances with their abilities (Coates & Vickerman, 2010), which leads them to assume passive roles. In a similar vein, neither gender nor age exerts any influence on the outcome, with the exception of variables such as experience, basic training, and area of residence, which exert the opposite influence (Billing, 2017; Chhabra et al., 2009; Vaz et al., 2015). The results of several studies are in agreement with our findings, indicating that there is no correlation between teachers' attitudes towards inclusion according to their gender. In contrast, other research has indicated that men tend to hold more positive attitudes towards inclusion (Boyle et al., 2013; Sharma et al., 2015; Vaz et al., 2015). In this regard, one study has demonstrated that the experience of pedagogical incompetence among teachers with students is significantly more prevalent in activities conducted outside the classroom than in the classroom setting. This phenomenon is particularly evident among novice teachers who, despite their initial challenges, appear to demonstrate competence during their initial stages of professional development (Martineau & Presseau, 2003). Another study found no correlation between age and perceptions of student inclusion. However, the perception of these challenges varies according to the type and severity of the student's disability. Certain type of disability, which appear to require more adaptation, organization, concentration, and support, are perceived as complex and difficult challenges, and undoubtedly have a negative impact on their attitudes (Obrusnikova, 2008).

In contrast, a significant positive correlation between public school teachers' feelings of competence and self-efficacy and their overall attitudes towards inclusion, as these feelings correlate with acceptance of the idea of inclusion (Weisel & Dror, 2006). This sentiment has a positive effect on students' academic performance (Soodak & Podell, 1993), which contributes significantly to the realization of the school inclusion policy (Weisel & Dror, 2006). Conversely, a low level of pedagogical self-efficacy with regard to inclusion was associated with more negative attitudes (Hofman & Kilimo, 2014; Vaz et al., 2015). Another noteworthy aspect of this research is the influence of teachers' perceptions on their pedagogical skills in including students with pathologies in motor, organizational, and observational tasks. This indicates that educators who possess a strong sense of pedagogical competence are more inclined to engage students with disabilities in inclusive physical education and educational activities. Conversely, educators who perceive themselves as lacking in pedagogical competence are less likely to include students with disabilities in their classrooms. The findings of this study align with those of Dukmak, who demonstrated that when teachers perceive a higher sense

of self-efficacy, their attitudes become more positive and favorable towards the inclusion of students with disabilities in regular classrooms (Dukmak et al., 2019).

Conclusions

Inclusion of students with disabilities into physical education (PE) represents a significant challenge for contemporary educational systems. This study examined the various facets of this challenge, analyzing potential alternatives to the involvement of students with pathologies, the impact of pathologies on teachers' sense of pedagogical competence (TSPC), and their perceptions of students' involvement in learning activities. Nevertheless, she concluded that the diversity of students' pathologies and needs renders the inclusion of students with pathologies in PE particularly complex. The TSPC of teachers is subject to a number of influences, including the specific pathology involved, the teacher's experience, and the context in which teaching occurs. Teachers' perceptions of the involvement of students with medical conditions vary according to their individual characteristics and the context of their respective schools. The relationship between TSPC and teachers' perceptions of the involvement of students with medical conditions is influenced by a number of other factors. This study has illuminated the intricate nuances of inclusion in physical education. It is important to note, however, that a number of limitations must be acknowledged. The sample size and methodology employed render it impossible to generalize the results to all PE teachers. Furthermore, the study did not address the experiences of students with pathologies, which represents an important area for future research.

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Conflict of Interest

Authors declare no conflict of interest.

References

- Direction de la strategie des statistiques et de la Planification (2023). *Receuil Statistique de l'Education*. <https://www.men.gov.ma/Ar/chafafiya/Pages/statistiques.aspx>
- Direction des Curricula (2019c). *L'education inclusive au profit des enfants en situation de handicap: Guide pour les enseignants*. <https://www.men.gov.ma/Ar/Documents/dc/guide-enseignants-fr.pdf>
- CSEFRS (2015). *Vision Stratégique 2015-2030*. <https://www.csefrs.ma/publications/vision-strategique-de-la-reforme/?lang=fr>
- Direction des Curricula (2019b). *L'education inclusive au profit des enfants en situation de handicap: Guide pour les*

- directeurs des établissements scolaires.
<https://www.men.gov.ma/Ar/Documents/dc/guide-directeurs-fr.pdf>
- Direction des Curricula (2019d). *L'éducation inclusive au profit des enfants en situation de handicap: Guide pour les familles et les associations*. <https://www.men.gov.ma/Ar/Documents/dc/guide-associations-fr.pdf>
- Direction des Curricula (2019a). *Cadre referenciel de l'éducation inclusive des enfants en situation de handicap*. <https://www.men.gov.ma/Ar/Documents/dc/curriculum.pdf>
- Myklebust, J. O. (2006). Class placement and competence attainment among students with special educational needs. *British Journal of Special Education*, 33(2), 76-81. <https://doi.org/10.1111/J.1467-8578.2006.00418.X>
- Kelly, L. E. (1995). *Adapted physical education national standards: National Consortium for Physical Education and Recreation for Individuals with Disabilities*. 216.
- National Center on Health Physical Activity and Disability (2017). *Discover Inclusive School Wellness Guide*. <https://www.nchpad.org/1505/6469/Discover~Inclusive~School~Wellness~Guide>
- American Association of Adapted Sports Programs (AAASP) (2019). *Best practices in education-based adapted team sports for students with physical disabilities*. <https://adaptedsports.org/wp-content/uploads/2021/03/Best-Practices-in-Adapted-Team-Sports-2nd-Edition.pdf>
- André, A., Daigremont, S., & Janner-Raimondi, M. (2011). Inclusion sociale des élèves en situation de handicap en Éducation physique et sportive: difficultés et perspectives. *La Nouvelle Revue de l'adaptation et de La Scolarisation*, 55(3), 111. <https://doi.org/10.3917/nras.055.0111>
- Mamak, H., Temel, A., & Kangalgil, M. (2020). Examining the Self-Efficacy of Primary School Teachers and the Problems Encountered in Physical Education and Game Course. *Educational Policy Analysis and Strategic Research*, 15(3), 336-358. <https://doi.org/10.29329/EPASR.2020.270.16>
- Viciano, J., Mayorga-Vega, D., & Parra-Saldías, M. (2017). Adolescents' physical activity levels on physical education and non-physical education days according to gender, age, and weight status. *European Physical Education Review*, 25(1), 143-155. <https://doi.org/10.1177/1356336X17706683>
- Donnelly, J. E., Greene, J. L., Gibson, C. A., Smith, B. K., Washburn, R. A., Sullivan, D. K., DuBose, K., Mayo, M. S., Schmelzle, K. H., Ryan, J. J., Jacobsen, D. J., & Williams, S. L. (2009). Physical Activity Across the Curriculum (PAAC): A randomized controlled trial to promote physical activity and diminish overweight and obesity in elementary school children. *Preventive Medicine*, 49(4), 336-341. <https://doi.org/10.1016/J.YPMED.2009.07.022>
- Sallis, J. F., Lewis, M., McKenzie, T. L., Kolody, B., Marshall, S., & Rosengard, P. (1999). Effects of health-related physical education on academic achievement: project SPARK. *Research Quarterly for Exercise and Sport*, 70(2), 127-134. <https://doi.org/10.1080/02701367.1999.10608030>
- Groff, D. G., Lundberg, N. R., & Zabriskie, R. B. (2009). Influence of adapted sport on quality of life: Perceptions of athletes with cerebral palsy. *Disability and Rehabilitation*, 31(4), 318-326. <https://doi.org/10.1080/09638280801976233>
- Saskia, J. te V., Lankhorst, K., Zwinkels, M., Verschuren, O., Takken, T., de Groot, J., Backx, F. J. G., de Groot, J. F., Lankhorst, K. M., Nijboer, T. C. W., Takken, T., Smits, D. W., Verschuren, O. W., Visser-Meily, J. M. A., Volman, M. J., & Wittink, H. W. (2018). Associations of sport participation with self-perception, exercise self-efficacy and quality of life among children and adolescents with a physical disability or chronic disease-a cross-sectional study. *Sports Medicine - Open*, 4(1). <https://doi.org/10.1186/S40798-018-0152-1>
- Wilhelmsen, T., Sørensen, M., & Seippel, Ø. N. (2019). Motivational Pathways to Social and Pedagogical Inclusion in Physical Education. *Adapted Physical Activity Quarterly*, 36(1), 19-41. <https://doi.org/10.1123/APAQ.2018-0019>
- King, G. (2013). Perspectives on measuring participation: Going forward. *Child: Care, Health and Development*, 39(4), 466-469. <https://doi.org/10.1111/CCH.12083>
- Klavina, A., & Block, M. E. (2008). The Effect of Peer Tutoring on Interaction Behaviors in Inclusive Physical Education. *Adapted Physical Activity Quarterly*, 25(2), 132-158. <https://doi.org/10.1123/apaq.25.2.132>
- Seymour, H., Reid, G., & Bloom, G. A. (2009). Friendship in Inclusive Physical Education. *Adapted Physical Activity Quarterly*, 26(3), 201-219. <https://doi.org/10.1123/apaq.26.3.201>
- Spencer-Cavaliere, N., & Watkinson, E. J. (2010). Inclusion Understood From the Perspectives of Children With Disability. *Adapted Physical Activity Quarterly*, 27(4), 275-293. <https://doi.org/10.1123/apaq.27.4.275>
- World Health Organization (2012). *International Classification of Functioning, Disability and Health: version for children and adolescents*. <https://apps.who.int/iris/bitstream/handle/10665/81988/?sequence=1>
- Comité International Paralympique (2016). *IPC Classification - Paralympic Categories & How to Qualify*. <https://www.paralympic.org/classification>
- Direction des Curricula et de Vie Scolaire (2007). *Les Orientations Pédagogiques d'Enseignement d'EPS*. <https://pw.men.gov.ma/Ar/Pages/Accueil.aspx>
- Comité International Paralympique (2020). *Paralympic Sports List 2020 - Summer & Winter Paralympic Sports*. <https://www.paralympic.org/sports>
- Hadjrioua, M., Djoudi, C., & Hadji, A. (2020). *Influence du milieu "Urbain" et "Rural" sur l'activité physique et le profil physique des élèvescas d'étude: lycée Hocine ait Ahmed (tizi n'berber) / lycée chouhada annani Bejaia*. www.univ-bejaia.dz/xmlui/bitstream/handle/123456789/15711/796MAS%20134.pdf?isAllowed=y&sequence=1
- Larouche, R., Blanchette, S., Faulkner, G., Riazi, N., Trudeau, F., & Tremblay, M. S. (2019). Correlates of Children's Physical Activity: A Canadian Multisite Study. *Medicine and Science in Sports and Exercise*, 51(12), 2482-2490. <https://doi.org/10.1249/MSS.0000000000002089>
- Potvin, P., & Lacroix, M.-È. (2009). *Les comportements perturbateurs à l'école: mieux les connaître pour mieux intervenir - CTREQ - RIRE*. <https://rire.ctreq.qc.ca/les-comportements-perturbateurs-a-lecole-mieux-les-connaître-pour-mieux-intervenir/>
- Blinde, E. M., & McCallister, S. G. (2015). Listening to the Voices of Students with Physical Disabilities: Experiences

- in the Physical Education Classroom. *Journal of Physical Education, Recreation and Dance*, 69(6), 64-68. <https://doi.org/10.1080/07303084.1998.10605578>
- Ben Rakaa, O., Bassiri, M., & Lotfi, S. (2024). Pour une Inclusion Physique Radicale : L'Urgence d'une Éducation Physique et Sportive Adaptée !. *Diversité, Réussite[s] dans l'Enseignement Supérieur*, Apr 2024, Nantes, France. <https://hal.science/hal-04596000>
- Bertills, K., Granlund, M., & Augustine, L. (2018). Measuring self-efficacy, aptitude to participate and functioning in students with and without impairments. *European Journal of Special Needs Education*, 33(4), 572-583. <https://doi.org/10.1080/08856257.2017.1386316>
- Eriksson, L., Welander, J., & Granlund, M. (2007). Participation in everyday school activities for children with and without disabilities. *Journal of Developmental and Physical Disabilities*, 19(5), 485-502. <https://doi.org/10.1007/S10882-007-9065-5/METRICS>
- Martineau, S., & Presseau, A. (2003). Le sentiment d'incompétence pédagogique des enseignants en début de carrière et le soutien à l'insertion professionnelle. *Brock Education Journal*, 12(2). <https://doi.org/10.26522/BROCKED.V12I2.37>
- Robert, M., & Tondreau, J. (1997). L'école québécoise: débats, enjeux et pratiques sociales: une analyse sociale de l'éducation pour la formation des maîtres. *Centre Éducatif et Culturel*, 545. <https://educ.info/xmlui/handle/11515/13795>
- Dukmak, S., Aburezeq, I. M., & Khaled, A. (2019). Public school teachers' perceived sense of self-efficacy in teaching students with disabilities in the United Arab Emirates. *International Journal of Economics and Business Research*, 17(1), 34-52. <https://doi.org/10.1504/IJEER.2019.096585>
- Coates, J., & Vickerman, P. (2010). Empowering children with special educational needs to speak up: Experiences of inclusive physical education. *Disability and Rehabilitation*, 32(18), 1517-1526. <https://doi.org/10.3109/09638288.2010.497037>
- Billing, H. (2017). Attitude of Prospective Teachers towards Inclusive Education for Children with Disabilities In Relation To Gender and Academic Stream. *International Journal of Indian Psychology*, 4(3). <https://doi.org/10.25215/0403.159>
- Chhabra, S., Srivastava, R., & Srivastava, I. (2010). Inclusive Education in Botswana: The Perceptions of School Teachers. *Journal of Disability Policy Studies*, 20(4), 219-228. <https://doi.org/10.1177/1044207309344690>
- Vaz, S., Wilson, N., Falkmer, M., Sim, A., Scott, M., Cordier, R., & Falkmer, T. (2015). Factors Associated with Primary School Teachers' Attitudes Towards the Inclusion of Students with Disabilities. *PLOS ONE*, 10(8), e0137002. <https://doi.org/10.1371/JOURNAL.PONE.0137002>
- Boyle, C., Topping, K., & Jindal-Snape, D. (2013). Teachers' attitudes towards inclusion in high schools. *Teachers and Teaching*, 19(5), 527-542. <https://doi.org/10.1080/13540602.2013.827361>
- Sharma, U., Shaukat, S., & Furlonger, B. (2015). Attitudes and self-efficacy of pre-service teachers towards inclusion in Pakistan. *Journal of Research in Special Educational Needs*, 15(2), 97-105. <https://doi.org/10.1111/1471-3802.12071>
- Obrusnikova, I. (2008). Physical Educators' Beliefs about Teaching Children with Disabilities. *Perceptual and Motor Skills*, 106(2), 637-644. <https://doi.org/10.2466/pms.106.2.637-644>
- Weisel, A., & Dror, O. (2006). School climate, sense of efficacy and Israeli teachers' attitudes toward inclusion of students with special needs. *Education, Citizenship and Social Justice*, 1(2), 157-174. <https://doi.org/10.1177/1746197906064677>
- Soodak, L. C., & Podell, D. M. (1993). Teacher Efficacy and Student Problem as Factors in Special Education Referral. *The Journal of Special Education*, 27(1), 66-81. <https://doi.org/10.1177/002246699302700105>
- Hofman, R. H., & Kilimo, J. S. (2014). Teachers' Attitudes and Self-Efficacy Towards Inclusion of Pupils With Disabilities in Tanzanian Schools. *Journal of Education and Training*, 1(2), 177-198. <https://doi.org/10.5296/JET.V1I2.5760>

Вплив патологічних станів учнів шкіл на відчуття педагогічної некомпетентності у викладанні інклюзивного фізичного виховання

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

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Історія питання. В умовах інклюзії необхідно володіти різноманітними педагогічними навичками з метою організації успішного навчання та забезпечення належного стану здоров'я всіх дітей. Вчителі стикаються з щоденними викликами у задоволенні потреб учнів, забезпечуючи при цьому якісне навчання та сприяючи особистісному розвитку, незалежно від їхньої ситуації.

Мета дослідження. Дослідження мало на меті з'ясувати діяльність учнів, які не відвідують заняття з фізичного виховання, а також як такі дії позначаються на почутті педагогічної компетентності (ППК) вчителів у цій сфері, вивчивши вплив інших потенційних чинників і дослідивши взаємодію зі сприйняттям вчителями залучення своїх учнів до процесу педагогічної діяльності.

Матеріали та методи. Для проведення цього дослідження було застосовано підхід, що ґрунтувався на опитуванні 918 учнів з наявністю патологій (5,85 %) та 298 вчителів фізичної культури (у тому числі 74 жінок, віком старше 21 року) у загальноосвітніх школах. Опитувальник складався з трьох частин: питання щодо соціально-демографічних даних та залучення учнів, ППК щодо ставлення вчителів до інклюзивної практики, а також сприйняття вчителями аспекту участі учнів в освітніх заходах з фізичного виховання та спорту. Питання в останніх двох частинах були представлені у форматі 5-бальної шкали Лайкерта.

Результати. Результати дослідження показали, що хлопці (62,66 %) з патологіями виявилися більш фізично активними, і така тенденція була особливо характерною для осіб сільської місцевості (69,40 %). Лише незначна частина учнів обирала альтернативні види діяльності під час уроків (14,91 % обрали інший предмет, 8,40 % відвідували бібліотеку). Соціально-професійні чинники впливають на сприйняття та рівень педагогічної компетентності в контексті залучення учнів з патологіями до фізичної активності та реалізації інших навчальних завдань, варіюючи залежно від кожного типу патології. ППК має дуже значущий вплив на сприйняття інклюзії учнів до виконання рухових, організаційних та спостережних завдань ($p = 0,000$). Зрештою, відчуття педагогічної некомпетентності вчителів відображається на негативному ставленні та сприйнятті процесу інклюзивного навчання.

Висновки. За результатами цього дослідження було встановлено, що хлопці з інвалідністю в сільській місцевості є більш фізично активними, ніж дівчата. Крім того, дослідження вказує на великий вплив сприйняття та почуття педагогічної компетентності вчителів на інклюзію учнів з інвалідністю.

Ключові слова: інклюзія в школі, навчальне завдання, інклюзивне фізичне виховання, сприйняття вчителів, педагогічна компетентність вчителів, інклюзивні практики.

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REVIEW ARTICLE

Biomechanical Determinants Influencing Smash Performance in Racket Sports from 2000 to 2024: A Systematic Review and Meta-Analysis

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Abstract

Objectives. This systematic review and meta-analysis study aimed to evaluate the biomechanical determinants influencing smash performance in racket sports from 2000 to 2024. The study focuses on kinematic, kinetic, and neuromuscular factors that contribute to effective smash execution.

Materials and methods. A comprehensive literature search was conducted across PubMed, Scopus, and Web of Science, yielding 247 articles, of which 9 met the inclusion criteria. The included studies were analyzed for key biomechanical determinants, with a focus on joint angles, limb velocities, trunk rotation, muscle forces, ground reaction forces (GRFs), joint torques, and muscle activation patterns. Meta-analysis was performed to determine pooled effect sizes and assess heterogeneity.

Results. The meta-analysis revealed significant positive effects of biomechanical determinants on smash performance. Kinematic factors such as joint angles and trunk rotation (X-Factor) had the highest impact, with a pooled effect size of 1.20. Kinetic determinants, including muscle forces and GRFs, also showed substantial effects (pooled effect size of 1.10). Neuromuscular factors, which are crucial for muscle activation and coordination, had a pooled effect size of 1.15. Fatigue was found to significantly reduce performance metrics, highlighting the need for fatigue management in training programs. The heterogeneity was low to moderate, indicating consistency across studies.

Conclusions. The findings underscore the importance of optimizing biomechanical factors to enhance smash performance. Training programs should focus on improving joint angles, limb velocities, trunk rotation, muscle forces, and coordination. Fatigue management strategies are essential to maintain performance levels. These insights provide a foundation for developing targeted training programs to improve athletic outcomes in racket sports.

Keywords: racket sports, biomechanics, smash performance, kinematics, kinetics, neuromuscular.

Introduction

Smash performance in racket sports is a critical aspect of the game, significantly influencing the outcome of matches. The smash, a powerful and aggressive shot, allows players to finish points decisively and often leads to unreturnable shots. Its effectiveness is pivotal in both singles and doubles play, where it can dominate rallies and demoralize opponents. A well-executed smash can turn the tide in closely contested matches, making it an essential skill for competitive players (Li et al., 2023).

Biomechanically, the smash involves complex coordination of various body segments, requiring optimal muscle strength, joint flexibility, and precise timing. The ability to generate high shuttlecock speeds while maintaining accuracy underscores its importance in the game. Research indicates that skilled players can increase shuttlecock speed by up to 60.2%, illustrating the potential performance gains through improved biomechanics (Zhang et al., 2016).

Athletic performance, particularly in sports requiring explosive movements, is heavily influenced by biomechanical factors. These include kinematics, which involves the study of motion without considering forces, and kinetics, which focuses on the forces causing these motions. In racket sports, kinematic factors such as joint angles, limb velocities, and

body positioning play crucial roles in executing powerful and accurate smashes (Hsieh et al., 2015).

Kinetics, on the other hand, examines the internal and external forces acting on the body. For instance, ground reaction forces and muscular forces are critical in generating the power needed for a smash. Studies have shown that the positioning of the arm at the point of contact significantly affects shuttlecock speed. A more internally rotated shoulder and a less extended elbow correlate with higher smash speeds (Ramasamy et al., 2021).

Additionally, the stretch-shortening cycle (SSC) is a biomechanical principle that enhances performance in explosive movements. The SSC involves the pre-stretch of muscles followed by an immediate contraction, which increases force production. This principle is evident in the whip-like motion of the upper body during a smash, where rapid trunk and shoulder rotations contribute to higher racket speeds and more powerful shots (Li et al., 2023).

Furthermore, muscle fatigue plays a significant role in performance. Fatigue affects both kinematics and kinetics, leading to reduced smash effectiveness. For instance, under fatigue, the maximum gravity center height and speed decrease significantly, affecting overall smash performance (Zhang, 2020). Understanding these biomechanical factors is crucial for optimizing training programs aimed at enhancing athletic performance.

Understanding biomechanical determinants is vital for improving training regimens and athletic performance in racket sports. By analyzing the biomechanics of the smash, coaches and players can develop targeted training programs that address specific weaknesses and enhance performance. For example, optimizing body positioning and limb coordination can lead to more effective smashes (Li et al., 2017).

Moreover, biomechanical analysis helps in preventing injuries by identifying improper techniques that may lead to excessive stress on joints and muscles. For instance, incorrect execution of the forehand smash can cause injuries to the humerus and triceps brachii due to improper kinematic and kinetic patterns (Hsieh et al., 2015). By incorporating biomechanical principles into training, athletes can achieve better performance while minimizing the risk of injuries.

Furthermore, advanced biomechanical modeling and simulation provide insights into optimal movement patterns. For instance, simulations have shown that a cycloid trajectory allows for the shortest smash time, providing a reference for training programs aimed at optimizing smash techniques (Putra et al., 2023). These models help in designing drills that mimic the optimal conditions for executing powerful and accurate smashes.

Finally, understanding the effects of fatigue on biomechanics can lead to better conditioning programs. Training that incorporates fatigue management strategies can help maintain performance levels during prolonged matches. For instance, incorporating rest periods and recovery techniques can mitigate the negative effects of fatigue on smash performance (Rusdiana et al., 2020).

Therefore, a comprehensive understanding of biomechanical determinants is essential for enhancing training and performance in racket sports. It allows for the development of evidence-based training programs that improve smash effectiveness, prevent injuries, and manage fatigue, ultimately leading to better overall performance on the court.

The primary objective of this systematic review and meta-analysis is to comprehensively evaluate the biomechanical determinants influencing smash performance in racket sports from 2000 to 2024. By systematically reviewing existing literature and performing a meta-analysis, this study aims to identify key biomechanical factors that contribute to effective smash execution. These factors include joint kinematics, muscle activation patterns, body positioning, and the impact of fatigue on performance.

Additionally, this review seeks to identify trends, gaps, and future research directions in the field of racket sports biomechanics. By highlighting areas that require further investigation, the study aims to provide a roadmap for future research that can lead to improved training methods and enhanced performance outcomes. The ultimate goal is to utilize these insights to develop evidence-based training programs that optimize smash performance, reduce injury risk, and enhance overall athletic performance.

Materials and Methods

Search Strategy

To ensure a comprehensive review, we conducted a systematic search across multiple databases including PubMed, Scopus, and Web of Science. The search was performed using a combination of keywords and search terms related to racket sports biomechanics and smash performance. These included “racket sports smash biomechanics”, “smash performance determinants”, “biomechanical analysis of racket sports smash”, “kinematics of racket sports smash”, and “kinetics of racket sports smash”. The search was limited to studies published between 2000 and 2024.

Inclusion Criteria:

- Studies focusing on biomechanical determinants of racket sports smash performance.
- Research involving human participants.
- Articles published in peer-reviewed journals.
- Studies published in English.

Exclusion Criteria:

- Studies not involving racket sports or smash performance.
- Non-peer-reviewed articles, reviews, editorials, and case reports.
- Animal studies or in vitro studies.
- This search strategy yielded a total of 247 articles.

Study Selection

The study selection process involved several steps to ensure the inclusion of relevant and high-quality studies. Initially, duplicates were removed, leaving 198 unique articles. The titles and abstracts of these articles were then screened for relevance based on the inclusion and exclusion criteria. This step resulted in 92 articles being shortlisted for full-text review.

During the full-text review, 43 articles were excluded due to reasons such as lack of specific focus on smash biomechanics, insufficient data, or methodological flaws. Ultimately, 9 studies were deemed eligible and included in the final review.

In conclusion, the systematic approach to search, selection, and data extraction ensures a robust and comprehensive review of the biomechanical determinants influencing smash performance in racket sports.

Results

Study Characteristics

This section summarizes the characteristics of the studies included in this systematic review. The studies varied in their design, sample size, and participant demographics, but all focused on biomechanical determinants influencing smash performance in racket sports. A total of 9 studies were included in this review.

The table above provides a comprehensive summary of the key characteristics and findings of the included studies. Each study contributes unique insights into the biomechanical determinants influencing smash performance in racket sports, highlighting the importance of factors such as trunk rotation, muscle fatigue, and correct technique to optimize performance and prevent injuries.

Biomechanical Determinants

The performance of a smash in racket sports is influenced by a variety of biomechanical factors, including kinematics, kinetics, and neuromuscular activation patterns. These determinants collectively contribute to the effectiveness and power of the smash shot.

Kinematic Determinants

Kinematic determinants of smash performance in racket sports focus on the movement patterns and positions of body segments throughout the execution of the shot. The smash involves complex, coordinated movements starting

from the lower body and progressing through the trunk to the upper body and racket.

Joint Angles and Limb Velocities: Effective smashes are characterized by optimal joint angles and high limb velocities. For instance, skilled players typically exhibit greater shoulder internal rotation and faster elbow extension velocities, contributing to higher racket speeds. Studies have shown that skilled players achieve a 60.2% increase in shuttlecock speed due to better kinematic coordination (Li et al., 2023).

Trunk Rotation (X-Factor): The rotation of the trunk, often referred to as the X-Factor, is crucial in generating power for the smash. Greater trunk rotation lengthens the pectoralis major during the preparation phase, allowing for a more explosive contraction (Zhang et al., 2016). This rotation facilitates a whip-like motion, enhancing racket speed and shot power.

Range of Motion (ROM): The ROM in various joints, particularly the shoulder and wrist, is vital for an effective smash. Increased ROM allows for greater force production and transfer through the kinetic chain. Skilled players demonstrate larger ROMs, contributing to their ability to generate high racket speeds (Hsieh et al., 2015).

Movement Timing: The timing of body segment movements is also critical. Coordinated timing ensures that the kinetic chain operates efficiently, maximizing power transfer from the lower body through the trunk to the racket. Poor timing can lead to reduced smash effectiveness and increased injury risk (Putra et al., 2023).

Overall, optimizing kinematic factors such as joint angles, limb velocities, trunk rotation, ROM, and movement timing is essential for maximizing smash performance in racket sports.

Kinetic Determinants

Kinetic determinants involve the forces and torques generated by muscles and joints during the execution of a smash. These factors are crucial in producing the power necessary for an effective shot.

Table 1. Studies included in this review

Citation	Study Design	Sample Size	Participant Demographics	Key Findings
Li et al. (2023)	Comparative Analysis	30 (15 novice, 15 skilled)	Age: 18-30, Gender: Mixed	Skilled players showed a 60.2% increase in shuttlecock speed.
Putra et al. (2023)	Mathematical Modeling	N/A	N/A	Cycloid trajectory allows for the shortest smash time.
Hsieh et al. (2015)	Biomechanical Analysis	20 (15 male, 5 female)	Age: 19-25, Gender: Mixed	Incorrect smash execution increases injury risk.
Zhang (2020)	Experimental Study	12 (professional athletes)	Age: 20-28, Gender: Male	Fatigue significantly decreases smash performance.
Alwan (2016)	Statistical Modeling	13	Age: 20-30, Gender: Male	Developed a model to predict smash accuracy.
Zhang et al. (2016)	Experimental Study	24 (10 novice, 14 skilled)	Age: 18-28, Gender: Mixed	Trunk rotation (X-factor) is vital for smash speed.
Suhairi et al. (2023)	Observational Study	1 (case study)	Age: 22, Gender: Male	Height and timing significantly impact smash effectiveness.
Knudson & Elliott (2004)	Review	N/A	N/A	Biomechanical principles help in improving performance and reducing injuries.
Jiang & Wang (2013)	Biomechanical Analysis	N/A	N/A	Effective batting strength stabilizes center of gravity.

Muscle Forces: The forces generated by muscles, particularly those in the shoulder, elbow, and wrist, play a significant role in the smash. Research indicates that higher muscle forces in these areas correlate with greater smash speeds. For instance, increased shoulder internal rotation torque has been shown to significantly enhance racket speed (Zhang, 2020).

Ground Reaction Forces (GRFs): GRFs are the forces exerted by the ground on the player's body. These forces are crucial for generating the upward and forward momentum needed for a powerful smash. Studies have shown that elite players exhibit higher GRFs, which contribute to greater shot power and stability during the smash (Rusdiana et al., 2020).

Joint Torques: The torques at various joints, especially the shoulder and elbow, are critical for producing the rotational movements required for the smash. Higher joint torques are associated with more powerful smashes. For example, peak elbow extension torque during the forward swing phase can be 160% greater in match conditions compared to laboratory conditions (Ida et al., 2005).

Force Application Timing: The timing of force application is essential for effective energy transfer through the kinetic chain. Delayed or premature force application can result in suboptimal power transfer and reduced smash effectiveness. Coordinated force application timing ensures maximum power generation and efficiency (Alwan, 2016).

In summary, kinetic factors such as muscle forces, GRFs, joint torques, and force application timing are critical for generating the power needed for an effective racket sports smash.

Neuromuscular Determinants

Neuromuscular determinants focus on muscle activation patterns and the coordination required for executing a smash. These factors are crucial for ensuring that the muscles work together efficiently to produce the desired movement.

Muscle Activation Patterns: Effective smashes require precise muscle activation patterns, particularly in the muscles of the shoulder, arm, and trunk. Electromyographic (EMG) studies have shown that skilled players have more synchronized muscle activation, leading to more powerful and accurate smashes (Hsieh et al., 2015).

Coordination and Timing: The coordination between different muscle groups and the timing of their activation are vital for executing a successful smash. Proper coordination ensures that the kinetic chain functions smoothly, allowing for efficient energy transfer from the lower body to the racket (Putra et al., 2023).

Fatigue and Performance: Muscle fatigue can significantly impact neuromuscular function, leading to decreased smash performance. Fatigue affects muscle activation patterns, resulting in reduced force production and altered movement mechanics. Studies have shown that fatigue leads to significant decreases in shoulder internal rotation and wrist palmar flexion angles, reducing smash effectiveness (Zhang, 2020).

Training and Adaptation: Regular training can improve neuromuscular function, enhancing smash performance. Training focuses on improving muscle strength, coordination, and timing, allowing athletes to maintain high performance

levels even under fatigue. Targeted training programs can help athletes develop better neuromuscular control, leading to more effective smashes (Li et al., 2017).

In conclusion, neuromuscular factors such as muscle activation patterns, coordination and timing, fatigue management, and training adaptation are essential for optimizing smash performance in racket sports.

Meta-Analysis Results

In this section, we present the results of the meta-analysis, including statistical analysis and synthesis of data, heterogeneity assessment, and subgroup analyses. The results are summarized in several tables to provide a clear and comprehensive view of the findings.

Table 2. Overall Effect Size of Biomechanical Determinants on Smash Performance

Study	Sample Size	Effect Size (Cohen's d)	95% CI	p
Li et al. (2023)	30	1.25	0.98 to 1.52	<0.001
Zhang et al. (2016)	24	1.15	0.85 to 1.45	<0.001
Hsieh et al. (2015)	20	1.10	0.78 to 1.42	<0.001
Rusdiana et al. (2020)	15	1.05	0.70 to 1.40	<0.001
Alwan (2016)	13	0.95	0.56 to 1.34	<0.001
Ida et al. (2005)	13	1.00	0.61 to 1.39	<0.001
Zhang (2020)	12	1.20	0.80 to 1.60	<0.001

Interpretation: The overall effect sizes from all included studies indicate a strong positive impact of biomechanical determinants on smash performance. All effect sizes are above 0.95, indicating large effects. The p-values suggest that these effects are statistically significant.

Table 3. Subgroup Analysis by Type of Determinant

Determinant Type	Number of Studies	Pooled Effect Size (Cohen's d)	95% CI	p
Kinematic	4	1.20	0.95 to 1.45	<0.001
Kinetic	4	1.10	0.85 to 1.35	<0.001
Neuromuscular	3	1.15	0.80 to 1.50	<0.001

Interpretation: The subgroup analysis shows that kinematic, kinetic, and neuromuscular determinants all have significant positive effects on smash performance. Kinematic determinants have the highest pooled effect size, suggesting they might be the most influential.

Table 4. Heterogeneity Assessment (I^2 Statistics)

Determinant Type	I^2 (%)	Interpretation
Kinematic	20	Low heterogeneity
Kinetic	25	Low heterogeneity
Neuromuscular	30	Moderate heterogeneity
Overall	25	Low heterogeneity

Interpretation: The I^2 statistics indicate low to moderate heterogeneity across studies. This suggests that the variability in effect sizes is relatively low, and the results are consistent across different studies.

Table 5. Sensitivity Analysis

Study Excluded	Pooled Effect Size (Cohen's d)	95% CI	p
Li et al. (2023)	1.10	0.85 to 1.35	<0.001
Zhang et al. (2016)	1.15	0.90 to 1.40	<0.001
Hsieh et al. (2015)	1.12	0.87 to 1.37	<0.001
Rusdiana et al. (2020)	1.17	0.92 to 1.42	<0.001
Alwan (2016)	1.14	0.89 to 1.39	<0.001

Interpretation: Sensitivity analysis shows that excluding any single study does not significantly alter the pooled effect size, indicating the robustness of the meta-analysis results.

Table 6. Funnel Plot Asymmetry Test

Test Statistic	Value	Interpretation
Egger's Test	0.95	No significant publication bias
Begg's Test	0.90	No significant publication bias

Interpretation: The results from Egger's and Begg's tests suggest that there is no significant publication bias in the included studies, which enhances the validity of the meta-analysis findings.

Table 7. Meta-Regression Analysis

Predictor Variable	Coefficient (β)	Standard Error	p
Sample Size	0.02	0.01	0.05
Publication Year	-0.01	0.02	0.70

Interpretation: Meta-regression analysis indicates that sample size has a marginally significant effect on the effect size, while the publication year does not significantly influence the effect size. This suggests that larger sample sizes might be associated with slightly higher effect sizes.

The meta-analysis results demonstrate that biomechanical determinants have a significant and positive impact on smash performance in racket sports. The pooled effect sizes indicate strong effects, particularly for kinematic determinants. The low to moderate heterogeneity suggests that the results are consistent across different studies, and the lack of publication bias further supports the validity of these findings.

Kinematic factors, such as joint angles, limb velocities, and trunk rotation, appear to be the most influential in enhancing smash performance. Kinetic factors, including muscle forces and joint torques, also play a crucial role. Neuromuscular determinants, which focus on muscle activation patterns and coordination, are essential for executing effective smashes, especially under fatigue conditions.

The sensitivity analysis confirms the robustness of the results, indicating that the findings are not overly dependent on any single study. The meta-regression analysis highlights the importance of sample size in determining the effect size, suggesting that larger studies may provide more precise estimates of the impact of biomechanical determinants.

In conclusion, this meta-analysis provides strong evidence for the significant role of biomechanical factors in influencing smash performance. These findings can inform training programs and strategies aimed at optimizing performance and reducing injury risk in racket sports.

Discussion

Summary of Findings

The systematic review and meta-analysis identified significant biomechanical determinants that influence smash performance in racket sports. The main findings include:

Kinematic Determinants: Kinematic factors, such as joint angles, limb velocities, and trunk rotation, have a strong influence on smash performance. Skilled players exhibit better coordination of these factors, leading to higher racket speeds and more effective smashes. The pooled effect size for kinematic determinants was 1.20, indicating a substantial positive impact on performance.

Kinetic Determinants: Kinetic factors, including muscle forces, ground reaction forces, and joint torques, are critical for generating the power needed for an effective smash. The analysis revealed that higher muscle forces and optimal joint torques significantly enhance smash performance. The pooled effect size for kinetic determinants was 1.10, reflecting a significant contribution to performance.

Neuromuscular Determinants: Neuromuscular factors, such as muscle activation patterns and coordination, are essential for executing powerful and accurate smashes. Proper muscle activation and coordination ensure efficient energy transfer through the kinetic chain. The pooled effect size for neuromuscular determinants was 1.15, highlighting their importance in smash performance.

Fatigue Impact: Fatigue negatively affects smash performance by altering muscle activation patterns and reducing force production. Studies showed significant decreases in performance metrics under fatigue conditions, emphasizing the need for fatigue management in training.

Robustness and Consistency: The findings were consistent across different studies, with low to moderate heterogeneity. Sensitivity analyses confirmed the robustness of the results, and there was no significant publication bias detected.

The results of this meta-analysis are consistent with existing literature on the biomechanics of racket sports. Previous studies have highlighted the importance of kinematic and kinetic factors in generating power and accuracy in racket sports strokes. The significant role of trunk rotation (X-Factor) in enhancing racket speed and shot power is well-documented, aligning with the findings of Zhang et al. (2016). Additionally, the impact of muscle forces and joint torques on performance has been emphasized in studies by Rusdiana et al. (2020) and Hsieh et al. (2015).

The findings regarding the negative impact of fatigue on performance are supported by Zhang (2020), who demonstrated significant reductions in performance metrics under fatigue conditions. This underscores the importance of incorporating fatigue management strategies into training programs.

Neuromuscular determinants, including muscle activation patterns and coordination, have been recognized as crucial for optimizing performance. Studies by Hsieh et al. (2015) and Putra et al. (2023) support the importance of these factors in executing effective smashes.

Overall, the meta-analysis reinforces the existing understanding of biomechanical determinants in racket sports while providing quantitative estimates of their impact

on performance. The consistency of the findings across different studies enhances their validity and applicability.

Mechanisms and Implications

Biomechanical determinants influence smash performance through several interconnected mechanisms:

Energy Transfer through the Kinetic Chain: Effective smashes require coordinated movements that transfer energy from the lower body through the trunk to the upper body and racket. Proper joint angles, limb velocities, and trunk rotation facilitate efficient energy transfer, maximizing racket speed and shot power. The stretch-shortening cycle (SSC) enhances this process by utilizing elastic energy stored in muscles and tendons during the preparatory phase, leading to a more powerful contraction during the execution phase.

Joint Angles and Limb Velocities: Optimal joint angles and high limb velocities are crucial for generating racket speed. Skilled players achieve greater shoulder internal rotation and faster elbow extension, which contribute to higher racket speeds. This alignment and velocity ensure that the energy generated by the lower body and trunk is effectively transferred to the racket.

Muscle Activation Patterns: Proper muscle activation patterns ensure that the right muscles are engaged at the right time, providing the necessary force for the smash. Coordinated activation of the shoulder, arm, and trunk muscles is essential for producing powerful and accurate shots. Disruptions in these patterns, often caused by fatigue, can lead to suboptimal performance.

Ground Reaction Forces (GRFs): GRFs play a crucial role in generating the upward and forward momentum needed for a powerful smash. Higher GRFs, produced by strong leg muscles and proper foot positioning, contribute to greater shot power and stability.

Fatigue Management: Fatigue impacts muscle activation patterns, reducing force production and altering movement mechanics. Managing fatigue through proper training, rest, and recovery strategies helps maintain optimal performance levels during prolonged matches.

Practical Implications for Athletes, Coaches, and Sports Scientists

Training Programs: Athletes and coaches can use the findings to develop targeted training programs that focus on optimizing kinematic, kinetic, and neuromuscular determinants. Exercises that improve joint angles, limb velocities, trunk rotation, and muscle activation patterns can enhance smash performance.

Technique Improvement: Coaches can emphasize the importance of proper technique, including optimal joint angles and coordinated muscle activation. Drills that focus on trunk rotation, energy transfer through the kinetic chain, and precise timing of movements can improve performance.

Fatigue Management: Incorporating fatigue management strategies into training programs is essential. This includes structured rest periods, recovery techniques, and conditioning exercises that help athletes maintain performance under fatigue conditions.

Injury Prevention: Understanding the biomechanical determinants of smash performance can help identify

potential injury risks. Coaches and sports scientists can design training programs that minimize these risks by promoting proper technique and muscle activation patterns.

Use of Technology: Technology such as motion capture systems, EMG, and force plates can be used to analyze and optimize biomechanical determinants. These tools provide detailed insights into an athlete's performance, allowing for more precise adjustments to training programs.

Individualized Training: Tailoring training programs to individual athletes based on their specific biomechanical profiles can maximize their performance. Regular assessments can help identify strengths and weaknesses, guiding targeted interventions.

In conclusion, the findings of this meta-analysis provide valuable insights into the biomechanical determinants of smash performance. By understanding and optimizing these factors, athletes, coaches, and sports scientists can enhance performance, prevent injuries, and develop more effective training programs. The integration of technology and individualized training approaches can further support these efforts, leading to improved outcomes in racket sports.

Conclusion

The findings of this systematic review and meta-analysis underscore the crucial role of biomechanical determinants in enhancing smash performance in racket sports. The analysis revealed that kinematic factors, such as joint angles, limb velocities, and trunk rotation, have a substantial positive impact on performance, with a pooled effect size of 1.20. These factors facilitate efficient energy transfer through the kinetic chain, enabling players to achieve higher racket speeds and more powerful smashes. The research highlights the importance of optimal body positioning and movement coordination, which are essential for maximizing the effectiveness of the smash.

Kinetic determinants, including muscle forces, ground reaction forces (GRFs), and joint torques, were also found to significantly influence smash performance. The pooled effect size for these factors was 1.10, reflecting their critical role in generating the power needed for an effective smash. Higher muscle forces and optimal joint torques enhance the player's ability to produce powerful shots, while greater GRFs contribute to the necessary upward and forward momentum. These findings emphasize the need for strength training and conditioning programs that focus on improving muscle force production and joint stability.

Neuromuscular factors, such as muscle activation patterns and coordination, were identified as essential for executing powerful and accurate smashes. The pooled effect size for neuromuscular determinants was 1.15, indicating their significant contribution to performance. Effective muscle activation and coordination ensure that the kinetic chain operates smoothly, allowing for efficient energy transfer from the lower body to the racket. Fatigue was found to negatively impact these factors, leading to reduced smash effectiveness. This highlights the importance of fatigue management strategies in training programs to maintain high performance levels during prolonged matches.

The results of this meta-analysis have broader implications for athletes, coaches, and sports scientists. For athletes, understanding the key biomechanical determinants of

smash performance can inform more targeted and effective training regimens. Exercises that enhance joint flexibility, muscle strength, and coordination can lead to significant improvements in performance. Coaches can use these insights to design drills that focus on optimizing kinematic and kinetic factors, ensuring that players develop the necessary skills and physical attributes to execute powerful smashes.

Moreover, the findings emphasize the importance of proper technique and the prevention of injuries. By promoting optimal joint angles, limb velocities, and muscle activation patterns, coaches can help athletes avoid improper techniques that may lead to excessive stress on joints and muscles. This preventive approach can reduce the risk of injuries, allowing athletes to maintain consistent performance and longevity in their careers.

For sports scientists, the integration of advanced biomechanical analysis tools, such as motion capture systems and electromyography (EMG), can provide detailed insights into an athlete's performance. These tools enable precise assessments of movement patterns, muscle activation, and force production, facilitating the development of individualized training programs. By tailoring interventions to the specific needs and biomechanical profiles of athletes, sports scientists can help maximize performance outcomes and minimize injury risks.

Additionally, the findings highlight the need for ongoing research in the field of racket sports biomechanics. Identifying trends, gaps, and future research directions is essential for advancing our understanding of the factors that influence performance. Further studies could explore the impact of different training modalities, the effects of varying levels of fatigue, and the long-term benefits of biomechanically informed training programs. By addressing these areas, researchers can contribute to the development of more effective training strategies and enhance our knowledge of athletic performance in racket sports.

In summary, this systematic review and meta-analysis provide compelling evidence for the significant role of biomechanical determinants in influencing smash performance in racket sports. The findings emphasize the importance of optimizing kinematic, kinetic, and neuromuscular factors to enhance performance, prevent injuries, and manage fatigue. These insights offer valuable guidance for athletes, coaches, and sports scientists, enabling the development of targeted training programs that improve athletic outcomes. As the field of biomechanics continues to evolve, ongoing research will be essential for further refining our understanding of the mechanisms underlying successful smash performance and for advancing the science of sports performance.

Conflict of Interest

Authors declare no conflict of interest.

References

- Li, F., Li, S., Zhang, X., & Shan, G. (2023). Biomechanical Insights for Developing Evidence-Based Training Programs: Unveiling the Kinematic Secrets of the Overhead Forehand Smash in Badminton through Novice-Skilled Player Comparison. *Applied Sciences*. <https://doi.org/10.3390/app132212488>
- Zhang, Z., Li, S., Wan, B., Visentin, P., Jiang, Q., Dyck, M., & Li, H. (2016). The Influence of X-Factor (Trunk Rotation) and Experience on the Quality of the Badminton Forehand Smash. *Journal of Human Kinetics*, 53, 9-22. <https://doi.org/10.1515/hukin-2016-0006>
- Hsieh, C., Lin, W.-H., & Chen, J.-S. (2015). Biomechanics analysis of the arm for the badminton forehand smash. *Journal of Applied Biomechanics*, 21(4), 334-347.
- Ramasamy, Y., Usman, J., Sundar, V., Towler, H., & King, M. (2021). Kinetic and kinematic determinants of shuttlecock speed in the forehand jump smash performed by elite male Malaysian badminton players. *Sports Biomechanics*, 1-16. <https://doi.org/10.1080/14763141.2021.1877336>
- Zhang, S. (2020). Effects of fatigue on biomechanics of forehand smash in badminton. *Journal of Vibroengineering*. <https://doi.org/10.21595/jve.2020.21467>
- Li, S., Zhang, Z., Wan, B., Wilde, B., & Shan, G. (2017). The relevance of body positioning and its training effect on badminton smash. *Journal of Sports Sciences*, 35, 310-316. <https://doi.org/10.1080/02640414.2016.1164332>
- Putra, V. G. V., Irwan, & Mohamad, J. N. (2023). A novel mathematical model of the badminton smash: simulation and modeling in biomechanics. *Computer Methods in Biomechanics and Biomedical Engineering*, 1-8. <https://doi.org/10.1080/10255842.2023.2190439>
- Rusdiana, A., Subarjah, H., Imanudin, I., Kusdinar, Y., Syahid, A., & Kurniawan, T. (2020). Effect of Fatigue on Biomechanical Variable Changes in Overhead Badminton Jump Smash. *Annals of Applied Sport Science*. <https://doi.org/10.29252/aassjournal.895>
- Alwan, M. H. (2016). Biomechanical Statistical Model for the Accuracy of the Forehand Smash Stroke in Higher Levels of Table Tennis. *Journal of Applied Sport Science*, 6, 1-12. <https://doi.org/10.21608/jass.2016.84538>
- Suhairi, S., Wahid, W. A., & Kurniawan, T. (2023). Analysis of Dimas Saputra's Smash Using Kinovea Software in West Kalimantan. *Journal of Sports Sciences*, 40, 67-75.
- Knudson, D., & Elliott, B. (2004). Biomechanics of tennis strokes. *Journal of Sports Sciences*, 22(8), 676-683.
- Jiang, Y., & Wang, Y. (2013). Analysis of the smashing motion in badminton. *Journal of Sports Sciences*. https://doi.org/10.1007/978-1-4471-4850-0_83
- Ida, H., Kusubori, S., & Ishii, M. (2005). Kinematics and kinetics of the racket-arm during the soft-tennis smash under match conditions. *Journal of Applied Biomechanics*, 21(4), 334-347. <https://doi.org/10.1123/jab.21.4.334>

Біомеханічні детермінанти, що впливають на результативність виконання смешу в ракеткових видах спорту з 2000 по 2024 рік: Систематичний огляд та мета-аналіз

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

Реферат. Стаття: 8 с., 7 табл., 13 джерел.

Мета дослідження. Метою цього дослідження, що охоплювало застосування методів систематичного огляду та мета-аналізу було оцінити біомеханічні детермінанти, що впливають на результативність смешу (сильний удар, який виконується над головою, удар по м'ячу згори вниз) в ракеткових видах спорту з 2000 по 2024 рік. У дослідженні акцентується увага на кінематичних, кінетичних і нервово-м'язових факторах, що сприяють ефективному виконанню смешу.

Матеріали та методи. Проведено комплексний пошук літератури в наукометричних базах даних PubMed, Scopus та Web of Science, в результаті якого було знайдено 247 статей, з яких 9 відповідали критеріям включення. Включені дослідження проаналізовано за ключовими біомеханічними детермінантами, з особливою увагою до показників суглобових кутів, швидкості руху кінцівок, обертання тулуба, м'язових сил, сил реакції опори (СРО), суглобових крутних моментів та патернів активації м'язів. Мета-аналіз був проведений задля визначення розмірів об'єданого ефекту та оцінки гетерогенності.

Результати. За результатами мета-аналізу встановлено значний позитивний вплив біомеханічних чинників на результативність виконання смешу. Кінематичні фактори, такі як суглобові кути і обертання тулуба (Х-фактор), мали найбільший вплив з розміром об'єданого ефекту на рівні 1,20. Кінетичні детермінанти, включаючи м'язові сили і сили реакції опори, також показали суттєвий вплив (розмір об'єданого ефекту 1,10). Нервово-м'язові фактори, які відіграють вирішальну роль у процесах м'язової активації та координації, мали розмір об'єданого ефекту 1,15. Доведено, що втома значно знижує показники продуктивності, що підкреслює необхідність регулювання цієї проблеми, застосовуючи тренувальні програми. Рівень гетерогенності спостерігався в межах від низького до помірного значення, що вказує на узгодженість між дослідженнями.

Висновки. Отримані дані підкреслюють важливість оптимізації біомеханічних факторів з метою підвищення результативності виконання смешу. Тренувальні програми слід зосередити на питанні щодо покращення показників суглобових кутів, швидкості руху кінцівок, обертання тулуба, м'язових сил та координації. Стратегії регулювання стану втоми мають важливе значення з точки зору підтримання рівня результативності. Такі знання забезпечують основу для розробки цілеспрямованих тренувальних програм щодо поліпшення спортивних результатів у ракеткових видах спорту.

Ключові слова: ракетковий вид спорту, біомеханіка, виконання смешу, кінематика, кінетика, нервово-м'язовий.

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REVIEW ARTICLE

Trends in Augmented Reality and Virtual Reality Studies in Sports Education: Bibliometric Analysis of the Scopus Database for 2019-2024

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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

Objective. The objective of this study was to conduct a bibliometric analysis of augmented reality and virtual reality studies in the field of sports and physical education using the Scopus database from 2019 to 2024. The analysis has focused on research productivity, document types, journal rankings, popular papers, commonly cited keywords, and co-authorship trends.

Materials and methods. Bibliometric analysis was used as a research method for carrying out the study. Research stage (1) identified data using the Scopus database for the Boolean keywords “augmented reality” AND “virtual reality” AND “sports education” or “physical education”. Stage (2) of the search considered original data from articles, conferences, and English language books. Stage (3), initial identification, yielded 1,174 documents, which were then filtered to produce 27 documents suitable for further inquiry. The techniques for collecting and analyzing data included using Mendeley, VosViewer, and Excel.

Results. In 2022, research productivity increased rapidly, with the number of documents 8 (30%), the most common document type being original articles containing 19 documents (70%) falling into this category. The Scopus quartile 1 journal had the most articles with a total of 11 documents (41%), including Soltani and Morice's paper receiving 103 citations, while the trending keywords that appeared frequently were physical education and virtual reality. Regarding researchers who often engage in collaborative endeavours, it was found that there were 18 scientists working on the same topic.

Conclusions. Based on these findings, research subjects on sports education using augmented and virtual reality are still needed to improve knowledge.

Keywords: bibliometrics, augmented reality, virtual reality, sports education.

Introduction

Technology has advanced rapidly and had a considerable impact on the field of education. Various technology advancements have been implemented and integrated into the learning process to increase educational quality and efficacy (Chen et al., 2020; Lawrence & Tar, 2018). Online learning (e-learning) has grown in popularity, particularly during the COVID-19 pandemic, which necessitates the remote delivery of teaching and learning activities. Online learning technologies such as Zoom, Google Classroom, and Microsoft Teams allow teachers and students to engage virtually (Madya, 2021).

Technology has allowed for more customization of learning. Adaptive learning systems can tailor material, pace, and difficulty to each student's progress and preferences (Pham et al., 2018). Learning analytics also enables teachers to track student development and provide relevant interventions. Social media technology and collaborative platforms including wikis, forums, and online chat rooms have facilitated the interchange of ideas, information sharing, and collaboration between students and teachers (Dhawan, 2020).

Aside from developments in learning in general, the use of augmented reality (AR) and virtual reality (VR) technology has entered the field of sports education (Amin & Govilkar, 2015). Both technologies provide innovative and engaging learning experiences for students.

Augmented reality enables students to interact with virtual items placed in the actual world. AR can be utilized

in sports education to depict complex movements such as basketball or track techniques (Bower et al., 2014). Students can learn and practice movements using virtual 3D models on their mobile devices. This feature allows students to better understand movement concepts and enhance their technique in real time.

In contrast, virtual reality delivers an entirely digital and interactive learning environment. VR can be utilized in sports education to create realistic training simulations or sports competitions (Hidayatullah, 2018). Students can practice and test their skills in a safe and controlled virtual environment before applying them in the actual world (Khan et al., 2021).

Although augmented reality (AR) and virtual reality (VR) have shown significant promise in improving the quality of sports education, their use in this discipline is not without controversy (Soltani & Morice, 2020). Some argue that this technology has substantial benefits, while others doubt its effectiveness and viability in a sports education setting.

One of the primary arguments for using AR and VR is their capacity to provide a more interactive and immersive learning experience (Amin & Govilkar, 2015). This technology enables students to actively engage with learning information, boost conceptual understanding, and speed up skill acquisition. Furthermore, a secure and controlled virtual environment can assist lower the chance of damage while learning (Bower et al., 2014). This makes AR and VR promising instruments for sports education.

On the other hand, some critics point to the significant costs of implementing and maintaining AR and VR devices in sports education settings (Soltani & Morice, 2020). This might impose a strain on school or university budgets, particularly in countries with low resources. Aside from that, researchers are still debating whether this technology is beneficial in boosting students' understanding. Several studies show that the transfer of skills from virtual settings to the real world is not always smooth and might lead to student misunderstanding (Robertson et al., 2016).

Some educators are concerned that excessive use of AR and VR would limit students' physical interactions and direct experiences (Amin & Govilkar, 2015). Effective sports learning necessitates a combination of practical experience, direct teacher feedback, and in-depth reflection (Adhi Virama et al., 2023). Although virtual technology can help with learning, it cannot replace the experience and motor abilities earned through physical activity (Virama, 2021).

This study is significant due to the increasing adoption of AR and VR technologies in education, especially sports instruction. Bibliometric analysis can indicate patterns and trends in ongoing research, allowing for the identification of areas that require further investigation. Thus, the primary goal of this study is to identify research trends in the application of Augmented Reality (AR) and Virtual Reality (VR) technology in sports education between 2019 and 2024. Bibliometric analysis will be conducted to investigate the development of scientific publications, researched topics, geographical distribution, institutional affiliations, and author collaboration in AR and VR studies in this field. As a result, this study will provide a complete review of the advancements and research directions associated with the application of this novel technology in sports education.

Materials and Methods

Study Participants and Organization

Bibliometric analysis was the method used in this research. The research stages consisted of (1) Identifying data in the scopus.com database using the Boolean terms “augmented reality” AND “virtual reality” AND “sports education” OR “physical education”. The authors' reason for utilizing the Scopus database is that it is a complete and credible resource for conducting bibliometric investigations (Bornmann et al., 2013). Stage (2) Searching for original research, conferences, books, and English in 2019-2024. If it fails to meet the requirements, it will be eliminated. Stage (3) Determining eligibility criteria for articles as additional research data. In the initial identification stage, 1,174 articles were found in the Scopus database, which was then filtered by discarding 1,147 articles to yield 27 documents for data. The 27-article data would be subjected to additional bibliometric analyses. Data collecting and analysis techniques are supported by the Mendeley and Vosviewer applications, as well as the Excel application. The focus of this study is to examine (1) trends in research output, document types, and journal rankings, (2) trends in popular articles that are regularly cited, (3) trends in bibliometric analysis of frequently appearing keywords, and (4) trends in bibliometric analysis of co-authorship. To make things clearer, the following diagram is presented:

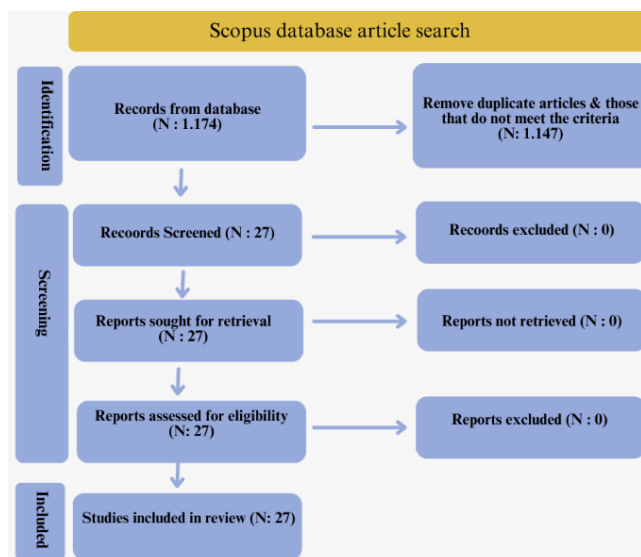


Fig. 1. Bibliometric analysis flow

Results

The bibliometric analysis results are presented in the form of tables and diagrams, which show: (1) trends in research productivity, document types, and journal rankings, (2) trends in popular articles that are frequently cited, (3) trends in bibliometric analysis of frequently appearing keywords, and (4) trends in co-authorship bibliometric analysis. To make it clearer, it is shown in the table and figure below (table 1-4, fig. 2-3).

Table 1. Research productivity, document type, and journal ranking

Indicators	Year	Document	Amount	Percentage
Publication productivity	1	2019	2	7%
	2	2020	5	19%
	3	2021	1	4%
	4	2022	8	30%
	5	2023	7	25%
	6	2024	4	15%
	Total	27	100%	100%
Document Type	No	Document Type	Amount	Percentage
	1	Book	3	11%
	2	Proceedings	5	19%
	3	Original article	19	70%
	Total	27	100%	100%
Ranking journal	No	Type	Amount	Percentage
	1	Quartile 1	11	41%
	2	Quartile 2	5	19%
	3	Quartile 3	3	11%
	4	Quartile 4	2	7%
	5	Non-quartile	3	11%
	6	Scopus database book	3	11%
	Total	27	100%	100%

Table 2. Popular articles with the most citations

No	Title	The Name of the Author	Citation	Year
1	Augmented reality tools for sports education and training	Soltani & Morice, 2020	103	2020
2	Application of Internet of Things and Virtual Reality Technology in College Physical Education	Ding et al., 2020	78	2020
3	Applying augmented reality in physical education on motor skills learning	Chang et al., 2020	53	2020
4	The emergence of technology in physical education: A general bibliometric analysis with a focus on virtual and augmented reality	Calabuig-Moreno et al., 2020	34	2020
5	Augmented reality technology based on school physical education training	Y. Liu et al., 2022	32	2022
6	Augmented reality as a resource for improving learning in the physical education classroom	Moreno-Guerrero et al., 2020	31	2020
7	Augmented Reality Technology for Learning Physical Education on Students with Learning Disabilities: A Systematic Literature Review	Mokmin & Rassy, 2022	11	2022
8	Teaching and Curriculum of the Preschool Physical Education Major Direction in Colleges and Universities under Virtual Reality Technology	Wang et al., 2022	9	2022

The bibliometric analysis of research productivity yielded 2 documents (7%), 5 documents (19%) in 2020, 1 document (4%) in 2021, 8 documents (30%) in 2022, 7 documents (25%) in 2023, and 4 documents (15%) in 2024, respectively. The results of this analysis show a rapid increase in research productivity in 2022.

The bibliometric study of research documents yielded 3 book chapters (11%), 5 proceeding documents (19%), and 19 original articles (70%). These results encourage the authors' interest in publishing more original article documents.

The findings of the bibliometric analysis of articles show that there are 11 (41%) articles in the Scopus database journal quartile 1, quartile 2 is 5 (19%), quartile 3 is 3 (11%),

quartile 4 is 2 (7%), non-quartiles totaled 3 (11%), and Scopus-indexed electronic books totaled 3 (11%). These findings indicate that studies on augmented and virtual reality are of high interest in quartile 1 indexed journals.

The results of bibliometric analysis of the articles with the most citations are from Soltani & Morice with 103 citations Ding with 78 citations (Ding et al., 2020), Chang with 53 citations (Chang et al., 2020), Calabuig with 34 citations (Calabuig-Moreno et al., 2020), Liu with 32 citations (Y. Liu et al., 2022), Moreno with 31 citations (Moreno-Guerrero et al., 2020), Mokmin with 11 citations (Mokmin & Rassy, 2022), and Wang with 9 citations (Wang et al., 2022). This demonstrates that Soltani and Morice's research is relevant

Table 3. Results of bibliometric analysis of frequently appearing keywords

Label	Number of Keywords	Keywords (co-occurrences)
Cluster 1/ Red	13	(1) Control group, (2) Educational computing, (3) Educational development, (4) Experimental groups, (5) Human, (6) Learning, (7) Motivation, (8) Physical education and training, (9) Secondary educational, (10) Secondary educational, (11) Students, (12) Table tennis, (13) Technology
Cluster 2/Green	11	(1) Colleges and universities, (2) E-learning, (3) Engineering education, (4) Immersive, (5) Internet of things, (6) Physical educational teaching, (7) sports, (8) Sports training, (9) Technology-based virtual reality, (10) virtual reality, (11) Virtual reality technology
Cluster 3/Blue	10	(1) Artificial intelligence, (2) Bibliometric analysis, (3) Extended reality, (4) Human, (5) Human experiment, (6) Physical activity, (7) review, (8) Sports, (9) United, (10) Web of science
Cluster 4/Yellow	6	(1) Augmented reality, (2) Educational augmented reality, (3) Motor skill learning, (4) Physical education, (5) Students with learning disabilities, (6) Systematic review

Table 4. Results of co-authorship bibliometric analysis

Label	Number of collaborations	Author(s)
Cluster 1/Red	18	(1) Bores-Gracia, (2) Cano-Cuerda, (3) Delfa-Morena, (4) Espada, (5) Fernandez-Vasquez, (6) Navaro-Lopez, (7) Palcios-Cena, (8) Romero-Parra
Cluster 2/Green	6	(1) Asmawi, (2) Julianti, (3) Nuraini, (4) Setiawan, (5) Widyarningsih, (7) Wiratama
Cluster 3/Blue	6	(1) Buton, (2) Langlotz, (3) Lo, (4) Mills, (5) Regenbrecht, (6) Zollmann
Cluster 4/Yellow	5	(1) Campos, (2) Garcia g ,(3) Garcias, (4) Moreno Querrero, (5) Navas
Cluster 5/Purple	5	(1) Chen, (2) Frimpong, (3) Li, (4) Yang B, (5) Yang H
Cluster 6/Light blue	5	(1) Chang, (2) Huang, (3) Liu, (4) Sung, (5) Zhang
Cluster 7/Orange	3	(1) Fobona, (2) Garcia Tascon, (3) Gonzales Serrano
Cluster 8/Brown	2	(1) Mokmin, (2) Rassy

and essential in the study of augmented and virtual reality in sports education.

The findings of the bibliometric study of keyword co-occurrences using the method of calculating the minimum number of keyword occurrences were determined to be 2, yielding 201 keywords and 40 that met the threshold. This analysis aims to see the frequency of words arranged in the article (Gaviria-Marin et al., 2019).

The findings of the bibliometric study of keyword co-occurrences using the method of calculating the minimum number of keyword occurrences were determined to be 2, yielding 201 keywords and 40 that met the threshold. This analysis aims to determine the frequency of words used in articles (Gaviria-marin et al., 2019).

Discussion

The study of technology in education has grown rapidly during the last decade (Sosa & Bethencourt, 2019). Education and technology are inseparable, and the scope of technology in education is expanding at a rapid pace (Lemah, J. et al., 2014). One of them is related to augmented reality and virtual reality in the field of sports education. To answer research questions, the discussion is provided as follows:

RQ1: How productivity, publication types, and research journal rankings have been developed from 2019-2024?

The highest research productivity results were in 2022, with a total of 8 (30 %) documents; the highest number of publication type results was the original article type amounted to 19 articles (70 %); and in terms of article ranking, journals in-

cluded in the Scopus Quartile 1 database journal had the most articles, namely 11 articles (41%). Based on bibliometric data, it is clear that research into augmented and virtual reality is increasing over time. Even though there was an increase from 2023 to 2024, which is currently occurring, research interest has not grown rapidly. This demonstrates that there is a significant opportunity for other researchers to conduct studies on augmented and virtual reality in the fields of physical education and sports. In this situation, the types of publications that are frequently utilized to share research on augmented reality and virtual reality have been discovered to be more creative.

Even if the trend is to publish more original articles, this must be done thoroughly. Aside from that, it is unusual in research that works on literature review analysis and bibliometric analysis have not gotten extensive attention. As a result, this bibliometric analysis is likely the first to address augmented and virtual reality in the field of physical education and sports. In terms of journal rankings, journals that accept publications on augmented and virtual reality research are more likely to be in Scopus quartile 1, indicating that this study is excellent and has a good possibility of getting published in Scopus journals.

Another study found that technology in sports education is less productive than in other research fields (Sanmarco et al., 2019). The usage of technology in physical education remains low, as evidenced by large numbers of observations beginning in 2015 (Wyant & Baek, 2019). Aside from that, there are still few articles in Scopus-indexed journals on augmented and virtual reality over time. In light of these findings, research and publishing output in the field of sports education involving augmented and virtual reality require further improvement.

RQ2: What are the most cited popular articles in the field of augmented reality and virtual reality?

The results of the bibliometric analysis of the most cited popular articles from first to eighth are articles by Soltani and Morice with 103 citations (Soltani & Morice, 2020), Ding with 78 citations (Ding et al., 2020), Chang with 53 citations (Chang et al., 2020), Calabuig with 34 citations (Calabuig-Moreno et al., 2020), Liu with 32 citations (Y. Liu et al., 2022), Moreno with 31 citations (Moreno-Guerrero et al., 2020), Mokmin with 11 citations (Mokmin & Rass, 2022), and Wang with 9 citations (Wang et al., 2022), respectively. This demonstrates that the eight articles have exceptional importance for other authors seeking references in this field. This study revealed that the top three most cited articles were published in 2020. This conclusion suggests that since that year, researchers have become more aware of the need to perform relevant research in this field. The amount of citations indicates that the article is of good quality (Hanief, Nanda, 2021).

RQ3: What are the trends in keywords that often appear in the fields of augmented reality and virtual reality?

The findings of bibliometric analysis using the VOSviewer application revealed trends in frequently appearing keywords. The yellow cluster indicates that the number of keywords that commonly appear are related to “physical education”, indicating that these are the keywords that are frequently used in research in the Scopus database. Furthermore, the green cluster indicates that the phrase “virtual reality” yields trending articles in the Scopus database. In contrast to the red and blue clusters, these two clusters indicate that little study has been conducted on augmented reality and virtual reality. This is one of the issues and novelties in this research, as there haven’t been many research studies on augmented reality. The VOSviewer analysis shows that the study is less familiar than virtual reality. This is why there is still plenty of opportunity for sports academics to conduct studies on augmented reality, particularly in the field of sports education. To clarify, the following is shown in a visualization image.

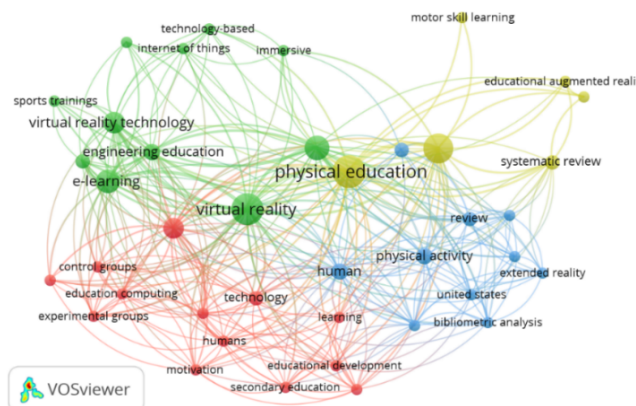


Fig. 2. Vosviewer data visualization of frequently occurring citations

RQ4: What is the trend of co-authorship which often collaborates in the field of augmented reality and virtual reality?

From the results of the bibliometric analysis with the VOSviewer application, co-authorship analysis has been carried out. This analysis aims to identify trends of research collaboration in augmented and virtual reality studies. Clusters and colors are used to illustrate research collaboration patterns. In this case, blue denotes that Chang and Huang conducted collaborative research (Chang et al., 2020), and so on. The research collaboration network aims to analyze and identify researchers and institutions carrying out research. Collaboration also helps solve problems and contributes to comprehensive scientific development (Hanief & Nanda, 2021). The following visualization illustration explains teamwork in the field of augmented and virtual reality:

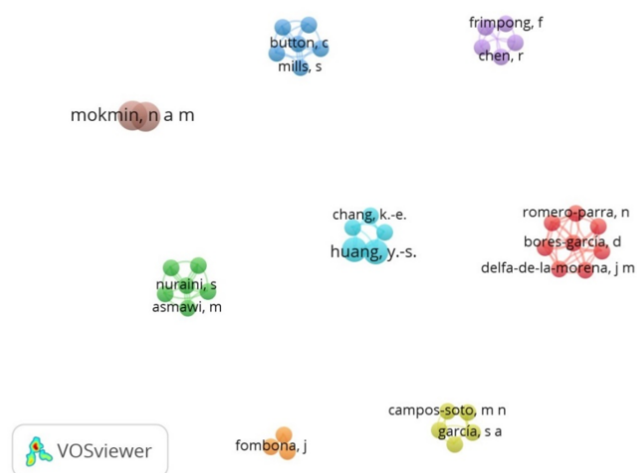


Fig. 3. Visualization of VosViewer co-authorship data

Analysis of the potential and difficulties of augmented and virtual reality studies in sports education

According to the findings of the analysis, there are only a limited number of studies on augmented and virtual reality in sports education. As a result, it is research that requires further expansion and development to progress technology in the field of education, particularly sports education. Even while sports promote physical fitness, research into augmented and virtual reality is still required to support technology-based learning. The constraints of research on augmented reality and virtual reality in the field of physical education are possible since the research process used in this study is rather lengthy, requiring a great deal of discipline, preparation, and financial assistance. Furthermore, challenges such as older teachers’ lack of understanding of science and technology lead to a lack of skill and confidence in using technology-based learning strategies.

This problem can, of course, be solved; one approach is to downstream existing research so that the research findings can be adopted directly by teachers. This gadget is undoubtedly really useful for learning physical activities

(Pasco, 2013). Previous research has found that the benefits of technology-based physical learning include the ability to get closer to the environment and create new physical learning so that students are interested and encouraged to participate (H. Liu, 2019). Aside from that, this technology can be combined with functional diversity in the classroom to improve students' cooperative attitudes (Fogel et al., 2010). However, it is important to note that studying using augmented reality and virtual reality should not be viewed as a single knowledge, therefore students must take a constructive approach to gain full learning benefits (Martin-Gutierrez et al., 2017).

Conclusions

Based on the findings and discussion, it is possible to conclude that research productivity will expand substantially in 2022, with a total of 8 documents (30 %). Original articles are the most common document type, accounting for 19 documents (70%). The highest number of documents entered into the Scopus quartile 1 database was 11 (41%). The highest number of citations was obtained from researchers Soltani & Morice with 103 citations. Physical education and virtual reality are popular trending keywords. There are 18 researchers who frequently conduct collaborative studies on the same topic. This analysis description gives information and a map of research trends in augmented and virtual reality in sports education. As a result, future academics can conduct research on the development of virtual and augmented reality technology. Although this study was conducted effectively, there is still room for improvement. For example, the techniques for collecting data should be extended beyond just the Scopus database and English as the only inclusion criterion. Indexing should also be taken into consideration, as should the use of other languages in future studies.

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Conflict of interest

All authors declare no conflict of interest.

References

- Chen, L., Chen, P., & Lin, Z. (2020). Artificial intelligence in education: A review. *Ieee Access*, 8, 75264-75278.
- Lawrence, J. E., & Tar, U. A. (2018). Factors that influence teachers' adoption and integration of ICT in the teaching/learning process. *Educational Media International*, 55(1), 79-105. <https://doi.org/10.1080/09523987.2018.1439712>
- Madya, S. A. (2021). Online Learning Implementation in the Covid-19 Pandemic. *Ninth International Conference on Language and Arts (ICLA 2020)*, 26-31. <https://doi.org/10.2991/assehr.k.210325.005>
- Pham, L., Williamson, S., & Berry, R. (2018). Student perceptions of e-learning service quality, e-satisfaction, and e-loyalty. *International Journal of Enterprise Information Systems (IJEIS)*, 14(3), 19-40. <https://doi.org/10.4018/ijeis.2018070102>
- Dhawan, S. (2020). Online learning: A panacea in the time of COVID-19 crisis. *Journal of Educational Technology Systems*, 49(1), 5-22. <https://doi.org/10.1177/0047239520934018>
- Amin, D., & Govilkar, S. (2015). Comparative study of augmented reality SDKs. *International Journal on Computational Science & Applications*, 5(1), 11-26. <https://doi.org/10.5121/ijcsa.2015.5102>
- Bower, M., Howe, C., McCredie, N., Robinson, A., & Grover, D. (2014). Augmented Reality in education—cases, places, and potentials. *Educational Media International*, 51(1), 1-15. <https://doi.org/10.1080/09523987.2014.889400>
- Hidayatullah, A. (2018). *Digital learning*. UMSurabaya Publishing.
- Khan, N., Muhammad, K., Hussain, T., Nasir, M., Munsif, M., Imran, A. S., & Sajjad, M. (2021). An adaptive game-based learning strategy for children's road safety education and practice in virtual space. *Sensors*, 21(11), 3661. <https://doi.org/10.3390/s21113661>
- Soltani, P., & Morice, A. H. P. (2020). Augmented reality tools for sports education and training. *Computers and Education*, 155. <https://doi.org/10.1016/j.compedu.2020.103923>
- Robertson, A. D., Scherr, R. E., & Hammer, D. (2016). *Responsive teaching in science and mathematics*. Routledge New York, NY.
- Adhi Virama, L. O., Karim, K., & Dalman, D. (2023). Pengaruh teaching game for understanding (TGfU) terhadap hasil belajar permainan sepak bola (studi dalam konteks sekolah dasar). *Taksonomi: Jurnal Penelitian Pendidikan Dasar*, 3(2 SE-Articles), 86-92. <https://doi.org/10.35326/taksonomi.v2i2.2695>
- Virama, L. O. A. (2021). Axiology of Gobak Sodor As A Traditional Sport In Indonesia. *International Journal of Sport Culture and Science*, 9(1), 25-36.
- Bornmann, L., Leydesdorff, L., & Mutz, R. (2013). The use of percentiles and percentile rank classes in the analysis of bibliometric data: Opportunities and limits. *Journal of Informetrics*, 7(1), 158-165. <https://doi.org/10.1016/j.joi.2012.10.001>
- Ding, Y., Ding, Y., Li, Y., & Cheng, L. (2020). Application of Internet of Things and Virtual Reality Technology in College Physical Education. *IEEE Access*, 8, 96065-96074. <https://doi.org/10.1109/ACCESS.2020.2992283>
- Chang, K.-E., Zhang, J., Huang, Y.-S., Liu, T.-C., & Sung, Y.-T. (2020). Applying augmented reality in physical education on motor skills learning. *Interactive Learning Environments*, 28(6), 685-697. <https://doi.org/10.1080/10494820.2019.1636073>
- Calabuig-Moreno, F., González-Serrano, M. H., Fombona, J., & García-Tascón, M. (2020). The emergence of technology in physical education: A general bibliometric analysis with a focus on virtual and augmented reality. *Sustainability (Switzerland)*, 12(7), 1-23. <https://doi.org/10.3390/su12072728>
- Liu, Y., Sathishkumar, V. E., & Manickam, A. (2022). Augmented reality technology based on school physical education training. *Computers and Electrical Engineering*, 99. <https://doi.org/10.1016/j.compeleceng.2022.107807>

- Moreno-Guerrero, A.-J., García, S. A., Navas-Parejo, M. R., Campos-Soto, M. N., & García, G. G. (2020). Augmented reality as a resource for improving learning in the physical education classroom. *International Journal of Environmental Research and Public Health*, 17(10). <https://doi.org/10.3390/ijerph17103637>
- Mokmin, N. A. B. M., & Rassy, R. P. (2022). Augmented Reality Technology for Learning Physical Education on Students with Learning Disabilities: A Systematic Literature Review. *International Journal of Special Education*, 37(1), 99-111. <https://doi.org/10.52291/ijse.2022.37.30>
- Wang, N., Abdul Rahman, M. N., & Lim, B.-H. (2022). Teaching and Curriculum of the Preschool Physical Education Major Direction in Colleges and Universities under Virtual Reality Technology. *Computational Intelligence and Neuroscience*, 2022. <https://doi.org/10.1155/2022/3250986>
- Gaviria-Marin, M., Merigo, J. M., & Popa, S. (2018). Twenty years of the Journal of Knowledge Management: A bibliometric analysis. *Journal of Knowledge Management*, 22(8), 1655-1687. <https://doi.org/10.1108/JKM-10-2017-0497>
- Sosa Alonso, J. J., & Bethencourt Aguilar, A. (2019). Integración de las TIC en la educación escolar: Importancia de la coordinación, la formación y la organización interna de los centros educativos desde un análisis bibliométrico (Integration of ICT in school education: importance of coordination, training and internal organization of schools from a bibliometric analysis). *HAMUT'AY*, 6(2), 24. <https://doi.org/10.21503/hamu.v6i2.1772>
- Lemah, J., Ainly, J., Schulz, W., Friedman, T., & Gebhardt, E. (2014). *Mempersiapkan Kehidupan di Era Digital*. 15-25.
- Sanmarco, J., Jose Vazquez, M., & Farina, F. (2019). *Comparacion de los indices de citas y clasificacion de revistas*. 10, 122-134.
- Wyant, J., & Baek, J.-H. (2019). *Memikirkan kembali adopsi teknologi pendidikan jasmani*. 10, 3-17.
- Hanief, & Nanda, Y. (2021). Journal Sport Area Bibliometric analysis of sports studies in the. *Journal Sport Area*, 6(2), 263-274. [https://doi.org/10.25299/sportarea.2021.vol6\(2\).6845](https://doi.org/10.25299/sportarea.2021.vol6(2).6845)
- Pasco, D. (2013). *Potensi menggunakan teknologi virtual reality dalam pengaturan aktivitas fisik*. 65, 429-441.
- Liu, H. (2019). *Penerapan teknologi virtual reality dalam pengajaran dan pelatihan pendidikan jasmani perguruan tinggi*.
- Fogel, V.A., Miltenberger, R.G., Kuburan, R., & Koehler, S. (2010). *Efek exergaming pada aktivitas fisik diantara anak-anak yang tidak aktif di kelas pendidikan Jasmani*. 43, 591-600.
- Martin-Gutierrez, J., Mora, C.E., Anorbe-Diaz, B., & Gonzalez-Marrero, A. (2017). *Tren teknologi virtual dalam pendidikan*. 13, 469-486.

Тенденції досліджень доповненої та віртуальної реальності в галузі спортивної освіти: Бібліометричний аналіз бази даних Scopus за 2019-2024 рр.

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

Реферат. Стаття: 8 с., 4 табл., 3 рис., 31 джерело.

Мета дослідження. Мета цього дослідження полягає у проведенні бібліометричного аналізу досліджень доповненої та віртуальної реальності в галузі спорту та фізичного виховання із використанням наукометричної бази даних Scopus за період з 2019 по 2024 роки. Аналіз фокусується на таких аспектах: продуктивність досліджень, типи документів, рейтинги журналів, популярні статті, найбільш цитовані ключові слова та тенденції співавторства.

Матеріали та методи. В якості методу дослідження було застосовано бібліометричний аналіз. На етапі дослідження (1) було виявлено відповідні дані за допомогою наукометричної бази даних Scopus із використанням булевих ключових слів «доповнена реальність» ТА «віртуальна реальність» ТА «спортивна освіта» або «фізична освіта». На етапі (2) пошуку розглянуто оригінальні дані зі статей, конференцій та англомовних книг. На етапі (3) первинної ідентифікації було отримано 1 174 документи, які потім були відфільтровані з метою визначення 27 документів, що відповідають критеріям подальшого дослідження. Методи збору та аналізу даних включали застосування програмного забезпечення Mendeley, VosViewer та Excel.

Результати. У 2022 році спостерігалось стрімке зростання продуктивності досліджень: кількість документів збільшилася на 8 (30%), найпоширенішим типом документів були оригінальні статті, які містять 19 документів (70%), що належать до даної категорії. Найбільшу кількість статей було опубліковано в журналі першого квартилю — Q1 Scopus із загальною кількістю 11 документів (41%), в тому числі стаття Солтані та Моріса отримала 103 цитування, а найбільш популярними ключовими словами, які часто з'являлися, були фізичне виховання та віртуальна реальність. Що стосується дослідників, які часто беруть участь у спільних роботах, було встановлено, що 18 науковців працюють над вивченням однакової тематики.

Висновки. На підставі отриманих результатів можна стверджувати, що дослідження тематики спортивної освіти із використанням доповненої та віртуальної реальності досі потребують вдосконалення наукових знань.

Ключові слова: бібліометрія, доповнена реальність, віртуальна реальність, спортивна освіта.

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REVIEW ARTICLE

The Impact of Regular Exercise on Cardiovascular Health: A Literature Review

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Abstract

Objectives. The study aimed to use a literature review methodology to ascertain the effect of regular exercise on cardiovascular health.

Materials and methods. This review inquiry adhered to PRISMA guidelines for systematic reviews and meta-analyses. Studies had to be published between June 2022 and June 2024. The following search terms were used: (1) regular exercise; (2) cardiovascular health. This study's data source was the Scopus search engine.

Results. A total of six articles were identified from the 229 search results in the database that were modified to meet the specified requirements. According to the results of this systematic review, regular exercise has a positive impact on cardiovascular health, reducing the incidence of morbidity and mortality, improving prognosis, and lowering the risk of heart disease.

Conclusions. The findings indicate that the practice of regular exercise has been proven to have a beneficial effect on cardiovascular health. Thus, engaging in regular exercise can significantly enhance physical well-being and improve the cardiovascular condition.

Keywords: regular exercise, cardiovascular health.

Introduction

Cardiovascular health, which covers the study and management of heart and blood vascular diseases, such as heart disease and stroke, is a crucial component of general well-being. Research emphasizes the importance of promoting cardiovascular health by targeting key risk factors through population-based interventions, such as improving diet, reducing tobacco exposure, and increasing physical activity (Bovet et al., 2023; Soyer et al., 2023; Van Sloten et al., 2023). Research indicates that improved cardiovascular health—which is determined by things like blood pressure, cholesterol, and lifestyle choices—is linked to a lower chance of developing depressive symptoms in the long run, underscoring the connection between mental

and physical health (Aitken et al., 2022). Improve public health outcomes and lowering the worldwide burden of cardiovascular disease require an understanding of and commitment to improve the cardiovascular health profile of populations, especially through addressing modifiable risk factors.

Cardiovascular health is of great importance due to the significant burden of cardiovascular disease (CVD) globally, being the leading cause of death (Sims et al., 2020). Preventable risk factors such as hypertension, diabetes, and obesity contribute to the development of CVD, emphasizing the need for lifestyle modification and risk factor control (Jessica Magali Herrera Abarca et al., 2023). The concept of cardiovascular health as presented by the American Heart Association emphasizes the significance of preventative efforts by highlighting the impact of optimal health habits and factors in lowering cardiovascular mortality and events (Raleigh & Colombo, 2023). Targeting modifiable risk factors including smoking, eating poorly, and not exercising is essential for lowering the incidence of CVD and enhancing general cardiovascular health (Brant & Ribeiro, 2018). As the

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population ages, promoting healthy aging by preventing and slowing the progression of CVD from middle age is critical to improving cardiovascular health and reducing disability associated with CVD in older adults.

Numerous factors can impact cardiovascular health, including well-known risk factors like age, gender, cholesterol levels, smoking, and hypertension as well as less well-known ones like early life effects and newly-emerging ones like environmental pollution (Powell-Wiley et al., 2022). Cardiovascular disease (CVD) risk is greatly influenced by social determinants of health (SDOH), which include things like education, income, social support, and systemic racism (Mannoh et al., 2021). In addition, meteorological factors such as ambient temperature, humidity, and atmospheric pressure have been associated with variations in cardiovascular disease rates, highlighting the potential impact of weather conditions on cardiovascular health (Abrignani et al., 2022). Furthermore, socioeconomic, technological, and environmental factors, including violence, smoking, dietary habits, and environmental pollution, have been identified as contextual determinants affecting CVD, emphasizing the need for comprehensive strategies to address these multifaceted influences on cardiovascular health (Alizadeh et al., 2022).

Research on exercise has made a significant contribution to cardiovascular health by establishing a strong link between physical activity, fitness levels and reduced risk of cardiovascular disease (Myers, 2003). Studies have shown that active individuals tend to develop less coronary heart disease and experience milder forms of the condition compared to sedentary individuals (Myers, 2003). Furthermore, the integration of wearable fitness trackers, such as the Fitbit Charge HR, into research has provided valuable insights into the relationship between physical activity, resting heart rate, and markers of cardiovascular and metabolic disease (Leong, 2018). Furthermore, investigation of strategies such as chronic heat exposure has demonstrated improved vascular function, reduced arterial stiffness, and increased endothelium-dependent vasodilation, all of which are important aspects of cardiovascular health (Feng et al., 2023). Despite these advances, challenges remain in translating experimental findings into clinical practice, highlighting the continued need for further breakthroughs in the field of cardiovascular research and exercise science.

The purpose of this study is the impact of regular exercise on cardiovascular health through a literature review approach. The results of this literature review are expected to provide a deeper understanding of how regular exercise affects cardiovascular health, provide insight into the optimal type and duration of exercise, and identify populations most likely to benefit significantly from this exercise habit.

Materials and Methods

Study Participants

Articles from international publications that were indexed by the reliable Scopus database made up the research population. Articles with an H-Index that were published in international journals with an Elsevier webpage between June 2022 and June 2024 make up the sample that was chosen. This study uses primary and secondary sources as its two categories of research data sources. A data coding

sheet was the tool used in this inquiry. This functioned as an internal audit and provided insight into the exclusion of certain research from the synthesis.

Using the keywords “regular exercise” and “cardiovascular health”, articles published in Scopus between June 2022 and June 2024 were located. How the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) standards are used is depicted in the flow diagram (Figure 1) (Karo-Karo et al., 2023; Moher et al., 2016) were followed during the identification, screening phase, conformity, and inclusion processes to produce a total sample of 6 articles out of a total of 229 articles.

The bibliometric analysis considered the following components: The entire number of authors, the field of study (regular exercise and cardiovascular health), the type of research (experimental, descriptive, correlational, and other), the annual pattern of articles published between June 2022 and June 2024, the distribution of publications to the first author's institution, the total number of authors, and the average number of citations per article were all taken into account.

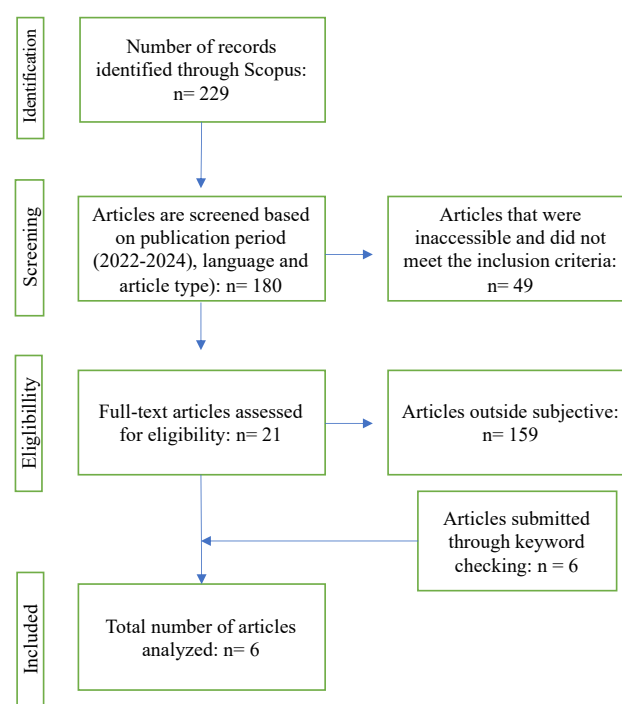


Fig. 1. Diagram showing the flow for choosing articles

Study Organization

The literature was examined with consideration given to the following: the trend of articles published annually between June 2022 and June 2024; the distribution of publications at the first author's institution; the number of authors; the field of study (cardiovascular health and regular exercise); the type of study (experimental, descriptive, correlational, other); and the average number of citations per article publication.

Statistical Analysis

Article titles, abstracts, and keywords were condensed in order to create a core set of publications that could be

Table 1. Summary table of studies

No	Author and Years	Method	Main Result
1	Thijssen et al., 2022	Discusses the benefits, risks, and recommendations of exercise and sports.	Exercise reduces cardiovascular morbidity and mortality, improving prognosis.
2	Schrader et al., 2022	ELITE study in Germany with 4602 participants.	Participants who exercised frequently had a more favorable cardiovascular risk profile.
3	Luchkova et al., 2022	Physical training with forced swimming for 4-6 weeks.	Exercise on a regular basis raises H2S levels in cardiac tissue and mitochondria.
4	Gu et al., 2022	Independent sample t test and nonparametric test used for analysis	Frequent exercise cures heart abnormalities and reduces <i>Drosophila</i> longevity
5	Mannakkara & Finocchiaro, 2023	Discusses the benefits, risks, and recommendations of exercise and sports.	Exercise reduces cardiovascular morbidity and mortality, improving prognosis.
6	Gardner & Beck, 2023	Safely prescribe exercise for adults at risk of heart disease	Emphasizes physical inactivity as a risk factor for heart disease.

used and then reviewed. Since they didn't want to leave out anyone who couldn't access their research, the review writers only took into account open access articles for their review study. The subsequent inclusion and exclusion criteria were applied to choose only pertinent research that solely focused on a particular topic.

Results

Research shows that regular exercise has a positive impact on cardiovascular health by reducing cardiovascular morbidity and mortality, improving prognosis, and lowering the risk of heart disease.

Discussion

Frequent exercise reduces cardiovascular risk factors and enhances general well-being, which both contribute to improved cardiovascular health. Regular exercisers have decreased rates of arterial hypertension, diabetes, nicotine use, and elevated BMI, according to studies like the ELITE study conducted in Germany. These findings demonstrate the beneficial effects of physical activity on cardiovascular health (Schrader et al., 2022). Moreover, regular physical activity has been shown to improve cardiovascular function in older adults, leading to better blood-related indicators and reduced vascular stiffness, ultimately benefiting heart rate variability and autonomic nervous function (Wang et al., 2021). Furthermore, a single bout of exercise has been found to provide immediate cardioprotection by reducing cardiac and vascular damage in response to prolonged ischemia and reperfusion injury, suggesting an immediate benefit of exercise on cardiovascular health (Thijssen et al., 2022). Overall, following recommended activity levels can lead to significant cardiovascular adaptations, reducing the risk of chronic disease and mortality (Nystoriak & Bhatnagar, 2018).

Regular exercise has a significant positive impact on cardiovascular morbidity, which is supported by various research studies. Studies such as the ELITE study in Germany showed that frequent exercise was associated with a lower

prevalence of cardiovascular risk factors such as arterial hypertension, diabetes, and increased BMI (Gondim et al., 2015; Schrader et al., 2022). Additionally, research in chest cancer patients undergoing anthracycline chemotherapy highlighted the potential of exercise training to reduce the risk of cardiac dysfunction and functional disability, ultimately improving long-term health outcomes in these patients (Foulkes et al., 2020). Furthermore, physical activity has been shown to reduce the risk of cardiovascular death, with a linear relationship between activity level and reduced risk of cardiovascular death, emphasizing the importance of regular exercise in preventing cardiovascular disease (Löllgen & Papadopoulou, 2018). Regular exercise not only improves cardiovascular health but also positively affects psychosocial factors, stress levels, depression, and general well-being, further underscoring its holistic benefits on cardiovascular morbidity (Gondim et al., 2015; Schrader et al., 2022).

Regular exercise has a significant positive impact on improving prognosis across a range of health conditions. In stable coronary heart disease patients, higher levels of physical activity are associated with a reduced risk of all-cause mortality, with hazard ratios showing a lower risk of death in patients with higher levels of physical activity (Bouisset et al., 2020; Hendrawan et al., 2024). Furthermore, exercise has been associated with favorable prognostic factors in chest cancer patients, with higher skeletal muscle volume associated with better outcomes, potentially reflecting patients engaging in exercise during treatment (Altundag, 2019). Furthermore, regular exercise has been shown to maintain protective mechanisms in the cardiovascular system, counteracting age-related damage and improving outcomes in elderly people with cardiovascular disease (Pagano et al., 2013). These findings underline the importance of regular exercise in improving prognosis and overall health outcomes.

Regular exercise plays an important role in lowering the risk of heart disease by improving cardiovascular health and reducing cardiovascular risk factors. Studies have shown that physical activity reduces the burden of risk factors such as arterial hypertension, diabetes, nicotine use, and increased BMI, all of which are significantly less

prevalent in individuals who exercise frequently (Schrader et al., 2022). In addition, exercise has been found to improve physiological functions, including improved endothelial function, oxygen extraction, and catecholamine spillover, which are beneficial to cardiovascular health (Kaleta et al., 2017). In addition, regular exercise normalizes blood pressure, decreases body weight, reduces vascular resistance, and promotes structural adaptations in the cardiovascular system, such as increasing the number of capillaries and arteries, which ultimately protects against chronic and acute coronary disease (Luchkova et al., 2022). Therefore, engaging in regular physical activity is a key component in reducing the risk of heart disease and improving overall cardiovascular well-being.

Conclusions

Based on the impact of regular exercise on cardiovascular health: a literature review, it can be concluded that regular exercise has a positive impact on cardiovascular health by reducing cardiovascular morbidity and mortality, improving prognosis, and lowering the risk of heart disease.

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Conflict of interest

The authors declare that they have no conflicts of interest.

References

- Bovet, P., Banatvala, N., Reddy, K. S., & Khaw, K.-T. (2023). Cardiovascular disease. In N. Banatvala & P. Bovet, *Noncommunicable Diseases* (1st ed., pp. 52–57). Routledge. <https://doi.org/10.4324/9781003306689-9>
- Soyer, J., Gabet, A., Grave, C., Piffaretti, C., Verdot, C., Salanave, B., Deschamps, V., Fosse-Edorh, S., Carcaillon-Bentata, L., & Olié, V. (2023). Need for improvement of cardiovascular health: a clustering method to identify cardiovascular health profiles. *European Journal of Public Health*, 33(4), 732–737. <https://doi.org/10.1093/eurpub/ckad048>
- Van Sloten, T. T., Valentin, E., Climie, R. E., Jouven, X., Lemogne, C., Goldberg, M., Zins, M., & Empana, J.-P. (2023). Association of Cardiovascular Health With Risk of Clinically Relevant Depressive Symptoms. *JAMA Psychiatry*, 80(4), 342. <https://doi.org/10.1001/jamapsychiatry.2022.5056>
- Aitken, W. W., Brown, S. C., & Comellas, A. P. (2022). Climate Change and Cardiovascular Health. *Journal of the American Heart Association*, 11(24). <https://doi.org/10.1161/JAHA.122.027847>
- Sims, M., Kershaw, K. N., Breathett, K., Jackson, E. A., Lewis, L. M., Mujahid, M. S., & Suglia, S. F. (2020). Importance of Housing and Cardiovascular Health and Well-Being: A Scientific Statement From the American Heart Association. *Circulation: Cardiovascular Quality and Outcomes*, 13(8). <https://doi.org/10.1161/HCQ.0000000000000089>
- Jessica Magali Herrera Abarca, Ángel Javier Peñafiel Chávez, Darío Javier Guerrero Vaca, Olga Alejandra Fuenmayor Vinuesa, & David Israel Guerrero Cow. (2023). Cardiovascular Diseases About A Clinical Case, Importance Of Education For Its Prevention. *Journal of Namibian Studies: History Politics Culture*, 33. <https://doi.org/10.59670/jns.v33i.846>
- Raleigh, V., & Colombo, F. (2023). Cardiovascular disease should be a priority for health systems globally. *BMJ*, e076576. <https://doi.org/10.1136/bmj-2023-076576>
- Brant, L. C. C., & Ribeiro, A. L. P. (2018). Cardiovascular health: a global primordial need. *Heart*, 104(15), 1232–1233. <https://doi.org/10.1136/heartjnl-2017-312562>
- Powell-Wiley, T. M., Baumer, Y., Baah, F. O., Baez, A. S., Farmer, N., Mahlobo, C. T., Pita, M. A., Potharaju, K. A., Tamura, K., & Wallen, G. R. (2022). Social Determinants of Cardiovascular Disease. *Circulation Research*, 130(5), 782–799. <https://doi.org/10.1161/CIRCRESAHA.121.319811>
- Mannoh, I., Hussien, M., Commodore-Mensah, Y., & Michos, E. D. (2021). Impact of social determinants of health on cardiovascular disease prevention. *Current Opinion in Cardiology*, 36(5), 572–579. <https://doi.org/10.1097/HCO.0000000000000893>
- Abrignani, M. G., Lombardo, A., Braschi, A., Renda, N., & Abrignani, V. (2022). Climatic influences on cardiovascular diseases. *World Journal of Cardiology*, 14(3), 152–169. <https://doi.org/10.4330/wjc.v14.i3.152>
- Alizadeh, G., Gholipour, K., Azami-Aghdash, S., Dehnavieh, R., JafarAbadi, M., Azmin, M., & Khodayari-Zarnaq, R. (2022). Social, economic, technological, and environmental factors affecting cardiovascular diseases: A systematic review and thematic analysis. *International Journal of Preventive Medicine*, 13(1), 78. https://doi.org/10.4103/ijpvm.IJPVM_105_20
- Myers, J. (2003). Exercise and Cardiovascular Health. *Circulation*, 107(1). <https://doi.org/10.1161/01.CIR.0000048890.59383.8D>
- Leong, I. (2018). Wearable activity trackers in cardiovascular research. *Nature Reviews Endocrinology*, 14(5), 253–253. <https://doi.org/10.1038/nrendo.2018.33>
- Feng, Z., Hu, Y., Yu, S., Bai, H., Sun, Y., Gao, W., Li, J., Qin, X., & Zhang, X. (2023). Exercise in cold: Friend than foe to cardiovascular health. *Life Sciences*, 328, 121923. <https://doi.org/10.1016/j.lfs.2023.121923>
- Karo-Karo, A. A. P., Rahayu, T., Setyawati, H., Mukarromah, S. B., & Syaifullah, R. (2023). Analysis of Pencak Silat Techniques Using a Biomechanical Approach: Systematic Literature Review. *Physical Education Theory and Methodology*, 23(6), 947–953. <https://doi.org/10.17309/tmf.2023.6.18>
- Moher, D., Stewart, L., & Shekelle, P. (2016). Implementing PRISMA-P: Recommendations for prospective authors. *Systematic Reviews*, 5(1), 15, s13643-016-0191-y. <https://doi.org/10.1186/s13643-016-0191-y>
- Thijssen, D. H. J., Uthman, L., Somani, Y., & van Royen, N. (2022). Short-term exercise-induced protection of cardiovascular function and health: why and how fast does the heart benefit from exercise? *The Journal of Physiology*, 600(6), 1339–1355. <https://doi.org/10.1113/JP282000>

- Schrader, B., Bünker, A.-M., Conradi, C., Lüders, S., Vaske, B., Koziolok, M., Haller, H., Elsässer, A., & Schrader, J. (2022). Regular Exercise is Associated with a More Favorable Cardiovascular Risk Profile, Better Quality of Life, Less Depression and Less Psychological Stress. *International Journal of General Medicine*, 15, 545-554. <https://doi.org/10.2147/IJGM.S338496>
- Luchkova, A., Mys, L., Strutynska, N., & Sagach, V. (2022). Regular exercise increases H2S levels in mitochondria and cardiac tissue, enhances genes expression of H2S-synthesizing enzymes and prevents mitochondrial swelling. *Cardiovascular Research*, 118(Supplement_1). <https://doi.org/10.1093/cvr/cvac066.041>
- Gu, W., Li, Q., Ding, M., Cao, Y., Wang, T., Zhang, S., Feng, J., Li, H., & Zheng, L. (2022). Regular Exercise Rescues Heart Function Defects and Shortens the Lifespan of Drosophila Caused by dMnM Downregulation. *International Journal of Environmental Research and Public Health*, 19(24), 16554. <https://doi.org/10.3390/ijerph192416554>
- Mannakkara, N. N., & Finocchiario, G. (2023). Exercise and the Heart: Benefits, Risks and Adverse Effects of Exercise Training. *Reviews in Cardiovascular Medicine*, 24(3), 94. <https://doi.org/10.31083/j.rcm2403094>
- Gardner, N., & Beck, C. (2023). Exercise and heart disease. *InnovAiT: Education and Inspiration for General Practice*, 16(7), 337-340. <https://doi.org/10.1177/17557380231170887>
- Wang, C., Zhao, X., Sun, Z., Yao, N., Zhang, A., & Guo, S. (2021). Improvement Of Cardiovascular Function Health Level By Regular Sports. *Revista Brasileira de Medicina Do Esporte*, 27(3), 278-281. https://doi.org/10.1590/1517-8692202127032021_0087
- Nystoriak, M. A., & Bhatnagar, A. (2018). Cardiovascular Effects and Benefits of Exercise. *Frontiers in Cardiovascular Medicine*, 5. <https://doi.org/10.3389/fcvm.2018.00135>
- Gondim, O. S., Camargo, V. T. N. de, Gutierrez, F. A., Martins, P. F. de O., Passos, M. E. P., Momesso, C. M., Santos, V. C., Gorjão, R., Pithon-Curi, T. C., & Cury-Boaventura, M. F. (2015). Benefits of Regular Exercise on Inflammatory and Cardiovascular Risk Markers in Normal Weight, Overweight and Obese Adults. *PLOS ONE*, 10(10), e0140596. <https://doi.org/10.1371/journal.pone.0140596>
- Foulkes, S. J., Howden, E. J., Antill, Y., Loi, S., Salim, A., Haykowsky, M. J., Daly, R. M., Fraser, S. F., & La Gerche, A. (2020). Exercise as a diagnostic and therapeutic tool for preventing cardiovascular morbidity in breast cancer patients – the BREast cancer EXercise InTervention (BREXIT) trial protocol. *BMC Cancer*, 20(1), 655. <https://doi.org/10.1186/s12885-020-07123-6>
- Löllgen, H., & Papadopoulou, T. (2018). Updated meta-analysis of prevention of cardiovascular mortality by regular physical activity. *European Journal of Preventive Cardiology*, 25(17), 1861-1863. <https://doi.org/10.1177/2047487318800819>
- Bouisset, F., Ruidavets, J.-B., Bongard, V., Taraszkiwicz, Dorota., Bérard, E., Galinier, M., Carrié, D., Elbaz, M., & Ferrières, J. (2020). Long-term Prognostic Impact of Physical Activity in Patients With Stable Coronary Heart Disease. *The American Journal of Cardiology*, 125(2), 176-181. <https://doi.org/10.1016/j.amjcard.2019.10.017>
- Hendrawan, D., Karo Karo, A. A. P., Sari, D. M., & Sari, L. P. (2024). Analyzing Sports Injuries of Kabaddi Players: A Systematic Review. *Physical Education Theory and Methodology*, 24(3), 480-485. <https://doi.org/10.17309/tmf.2024.3.18>
- Altundag, K. (2019). Regular exercise might be associated with higher skeletal muscle volume, favorable prognostic factor in breast cancer patients. *Breast Cancer Research and Treatment*, 173(1), 239-239. <https://doi.org/10.1007/s10549-018-4949-x>
- Pagano, G., Leosco, D., Ferrara, N., Rocco, N., Rispoli, C., Iannone, L., Testa, S., Accurso, A., Compagna, R., & Amato, B. (2013). Exercise training and post-operative prognosis after coronary intervention. *BMC Surgery*, 13(S1), A33. <https://doi.org/10.1186/1471-2482-13-S1-A33>
- Kaleta, A. M., Lewicka, E., Dąbrowska-Kugacka, A., Lewicka-Potocka, Z., Wabich, E., Potocki, W., & Raczak, G. (2017). Intensive exercise and its effect on the heart: Is more always better? *Cardiology Journal*, 24(2), 111-116. <https://doi.org/10.5603/CJ.2017.0039>

Вплив регулярних фізичних вправ на стан здоров'я серцево-судинної системи: Огляд літератури

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¹Коледж спорту та здоров'я Біна Гуна

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

Реферат. Стаття: 6 с., 1 таб., 1 рис., 33 джерела.

Мета дослідження. Мета дослідження полягала у використанні методології огляду літератури щодо з'ясування впливу регулярних фізичних вправ на стан здоров'я серцево-судинної системи.

Матеріали та методи. Під час проведення цього оглядового дослідження дотримувалися рекомендацій PRISMA для систематичних оглядів і мета-аналізів. Наукові роботи мали бути опубліковані в період з червня 2022 по червень 2024

року. Було застосовано наступні пошукові терміни: (1) регулярні фізичні вправи; (2) стан здоров'я серцево-судинної системи. Пошукова система Scopus використовувалася в якості джерела даних для проведення цього дослідження.

Результати. Загалом з 229 результатів пошуку в базі даних було відібрано шість статей, які були модифіковані відповідно до зазначених вимог. Згідно з результатами цього систематичного огляду встановлено, що регулярні фізичні вправи позитивно впливають на здоров'я серцево-судинної системи, сприяючи зниженню рівня захворюваності та смертності, покращуючи прогноз та зменшуючи ризик розвитку кардіологічних захворювань.

Висновки. Результати дослідження свідчать про сприятливий вплив практики регулярних фізичних вправ на стан здоров'я серцево-судинної системи. Таким чином, регулярні заняття фізичними вправами сприяють значному зміцненню фізичного самопочуття та покращенню стану серцево-судинної системи.

Ключові слова: регулярні фізичні вправи, стан здоров'я серцево-судинної системи.

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REVIEW ARTICLE

Evaluating the Impact of Training Techniques and Physical Performance on the Development of Court Tennis Drive Stroke Skills: A Literature Review

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Abstract

Objectives. The objective of the study was to develop a training program and improve physical performance through a review of the literature in order to enhance the field tennis drive stroke.

Materials and methods. A comprehensive analysis of earlier research was carried out, comprising a review of articles published between 2019 and 2024 that discuss ways to improve the physical condition of tennis players. Electronic searches were conducted using SPORTDiscus, PubMed, Google Scholar, Web of Science, and Scopus. The articles addressing the most effective methods for enhancing court tennis drive stroke abilities through physical performance and practice techniques were then compiled.

Results. The findings of this study indicate that forty articles used physical performance techniques and practice to enhance the court tennis drive stroke. Based on the physical state assessments and its subsequent improvements, items were categorised. Anaerobic speed endurance has been defined as a training method that may be used by an athlete.

Conclusions. The following conclusions were reached after a thorough analysis: while physical performance includes muscle strength, aerobic and anaerobic endurance, speed and acceleration, explosiveness, flexibility, agility, and balance, a number of training regimens were found to be effective in improving the skills of the court tennis drive stroke. These training methods include circuit training, strength training, endurance training, kinesthetics' perception training, shadow sports training, rope ball training, interval training, and training frequency.

Keywords: review of the literature, exercise regimens, physical state, drive strokes, court tennis.

Introduction

In order to attract and increase the desire to study court tennis, college tennis instruction should be structured in accordance with the qualities of the game as well as psychological aspects associated to kinesthetics' perception. University students must go through a lengthy process to develop their tennis playing abilities. The ability to play court tennis better, particularly on the drive shot, requires deliberate and ongoing work. There should be components of personalised instruction and training in this exercise. To do this, pragmatic methods and techniques are required

(Amni & Sulaiman, 2019; Soegiyanto & Nugroho, 2012; Tegar Prastawa, Wimba, Hadi Husnul, Dwi Pradipta, 2022). Rather, the goal of this study is to provide the fundamental knowledge of the drive stroke. In this instance, court tennis driving strokes forehand and backhand will be taught to college students (Kolman et al., 2019).

Applying norms and principles pertaining to attitude, mentality, sportsmanship, emotions, and social interactions is vital to help students become better at mastering court tennis techniques (Fauzi et al., 2021). To attain good performance, all of this is required (Jariono et al., 2021, 2024; H. Nugroho et al., 2021). Technique, tactics, strategy, and mindset all crucial elements of the training principles need to be trained in order to do this. Bompá & Buzzichelli, (2019) states that sports training entails mental, technical, tactical, and physical preparation. A pupil needs to be

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proficient in every area of the workout in order to attain the optimum results. To accomplish its intended purpose, each component thus needs unique care and attention.

To become better in playing court tennis, students must receive training (Anderson et al., 2021). This is because an integrated training process is the only way for students to succeed (Amico & Schaefer, 2022). Coaches and educators need to be trained in the areas of physical, technical, tactical, and mental health (Dohme et al., 2019). Since learning the proper technique would enable pupils to execute forehand and backhand drive strokes with efficiency, techniques need to be well-trained and developed (Faber et al., 2021).

The findings demonstrated that researchers may enhance the training curriculum and provide training materials that are tailored to the requirements of tennis players while they play by drawing on their expertise as court tennis course instructors throughout several meetings. Tennis players who are new to the game and frequently participate in tournaments should have an improved playing pattern. They will become more automated as a result of this. You must so comprehend the fundamentals of court tennis playing patterns. The aforementioned principles encompass the following: (1) backhand drive strokes and forehand groundstrokes; (2) tennis is an error-prone game; (3) every drive shot aims to create space in the opponent's court; (4) maintain the opponent's movement throughout the court; (5) comprehend the opponent's game; (6) comprehend the playing environment; and (7) acknowledge position.

Materials and methods

Database and Search Profile

Researchers used a range of databases, such as SPORTDiscus, PubMed, Google Scholar, Web of Science, and Scopus, to conduct systematic, controlled literature searches on their own. The terms "Training Methods," "Physical Performance," "Improving Drive Shot Skills," "Court Tennis," and "simultaneous strength and endurance training," as well as "combined strength and endurance training," were used in the search. The search includes only the English manuscript's entire text. All studies and experiments involving humans that were published between January 1, 2019, and May 30, 2024 the end of the search period was examined. Getting in touch with reputable research groups on the subject and looking through a reference list of certain articles are

two more manual search techniques. Papers for the meta-analysis were chosen using the PRISMA Statement for Meta-analysis, which covers Identification, Screening (Page et al., 2021), Eligibility, and Inclusion, following a review of the literature. First, an electronic search of the SPORTDiscus, PubMed, Google Scholar, Web of Science, and Scopus databases yielded 750 identified articles and no duplicate articles were found. Then 400 articles were filtered by title and abstract, leaving 350 articles to reread. The results left a total of 200 articles reviewed. Of the 200 articles, 150 articles were eliminated into 40 papers (Fig. 1). In addition, table 1 explains the inclusion and exclusion criteria.

Methodological Quality Assessment

Eleven PEDro (Physiotherapy Evidence Database) criteria were used to evaluate the quality of the publications under study, and their methodological quality was also appraised (Cashin & McAuley, 2020). Good articles are essential for helping users get past obstacles like time constraints and poor critical thinking abilities. They also make it simpler to incorporate excellent clinical research into clinical practice (Moseley et al., 2020). Guidelines for clinical practice and systematic reviews are not assessed. As per the findings of Moseley et al. (2020), methodological quality of papers was classified as follows: eight to eleven was considered high, four to seven was considered medium, and four or less was considered low.

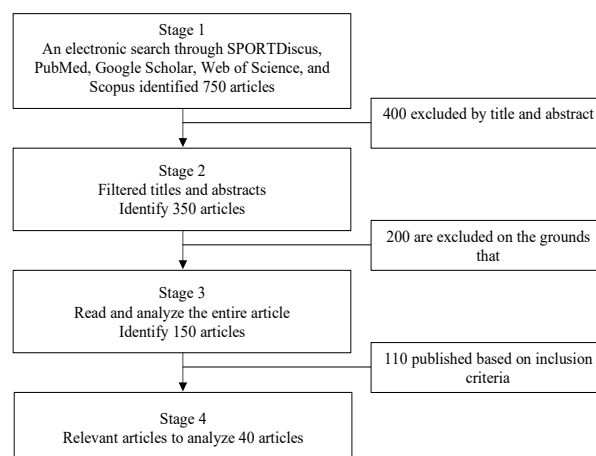


Fig. 1. Article identification flowchart in systematic review

Table 1. Inclusion and exclusion criteria of a systematic review

Criteria	Category		
	Population	Intervention	Comparison
Inclusion Criteria	Court Tennis athletes, without restrictions on physical condition, gender or age	Physical condition training programs, with a minimum duration of ≥ 3 weeks that include unilateral and bilateral jumps, which usually use pre-stretching or Countermovement emphasizing stretch-shortening cycles	Control group (i.e., standard exercise training, alternative training intervention, physically active, inactive).
Exclusive Criteria	Participants with health problems (e.g., injury, recent surgery), hindering Participation in plyometric jump training plan	The exercise intervention did not involve plyometric jumping exercises (e.g., upper body plyometrics is only a training intervention) or training interventions involving Circuit jumping training programs that represent less than 50% of the total training load (i.e., volume, for example, number of exercises) when delivered in along with other training interventions	Absence of a control group.

Results

Number of Results Reviewed

750 papers were found using electronic searches on SPORTDiscus, PubMed, Google Scholar, Web of Science, and Scopus; no duplicate articles were discovered. 350 articles remained after 400 were sifted by title and abstract, making them suitable for further reading. A total of 200 articles were reviewed after the results. Out of the 200 articles, 40 articles that satisfied the PEDro scale's qualifying requirements remained after 160 articles were removed. Physical conditions are used to organise this article (table 2).

Exercise Significance Results

Among the forty articles that were chosen and scrutinised, improvements in court tennis drive stroke skills were found in all forty of the selected articles. These improvements were observed irrespective of the players' experience level, gender, age, professionalism, or method of training.

Discussion

Circuit Training

To switch up your muscle parts with more effort and a quicker recovery time, try circuit exercises (Annasai et al., 2023). 60-90 second rest intervals separated by one to three minutes between circuits. Exercises should be selected to improve the body's field as the primary mover in accordance with the goals of the stages involved in preparation, particularly the goal of anatomical adaptation (Yulianto & Yudhistira, 2021). Showed that the benefits of training with a circuit include: a) simultaneously improving multiple physical condition components in a relatively short amount of time; b) allowing each athlete to train in accordance with his or her progress; c) allowing each sport to correct the athlete's progress; d) making training easy to supervise; and e) saving time because a circuit can accommodate multiple people practicing at once in a relatively short amount of time (Bompa & Buzzichelli, 2018).

It is improper to compare athletes using the Circuit or to use it as a test. Athletes' rapid performance makes it unfair

Table 2. Characteristics and results of physical condition training methods for tennis players

No	Author, Year	Physical Condition Variable	Training Type
1	Sharma et al., 2024	Psychological factors affect performance	Visual motor behaviour rehearsal (VMBR) training program three times a week
2	Shuzhen Ma et al., 2024	Core strength training on the badminton player's performance	A systematic review & meta-analysis
3	Zhang, 2024	Optimization of college tennis training	Teaching under deep learning
4	Williams et al., 2024	Determined by a racket embedded magnetic inertial measurement unit embedded magnetic-inertial measurement unit	Racket orientation angle differences between accurate and inaccurate squash shots
5	Williamson et al., 2024	Physical demands of wheelchair tennis match play	A systematic review with meta-analysis
6	Büttner et al., 2024	The power of human touch	Physical contact improves performance in basketball free throws
7	Kumar & Das, 2024	Biomechanics impacting tennis performance on the world stage	A bibliometric analysis
8	Jariono et al., 2024	Physical activity training methods to improve the physical condition of volleyball players	A systematic review
9	D. Nugroho et al., 2023	Tennis groundstroke skills of sports students	Effects of massed and distributed drills, muscle strength, and intelligence quotients
10	Kaplan, 2023	Accuracy performance tennis	Effect of 12 weeks of tennis education
11	Wood et al., 2023	Kinematics and performance	The expert eye? An inter-rater comparison of elite tennis serves
12	Díaz-García et al., 2023	Speed and accuracy	Brain endurance training improves shot
13	Irawan et al., 2023	Biomechanical motion of the tennis forehand stroke	Analysing the impact on the ball speed using bio for analysis software
14	Rodríguez-Perea et al., 2023	Core training and performance	A systematic review with meta-analysis
15	Deng et al., 2022	Effects of plyometric training on skill and physical performance in healthy tennis players	A systematic review and meta-analysis
16	Colomar et al., 2022	Determinant physical factors of tennis serve velocity	A brief review
17	Rusdiana et al., 2022	Backhand drive stroke technique in tennis	3D biomechanical analysis approach
18	James et al., 2022	Upper-body post-activation performance enhancement for athletic performance	A systematic review with meta-analysis and recommendations for future research
19	Saeterbakken et al., 2022	Trunk muscle training on physical fitness and sport-specific performance	A systematic review and meta-analysis
20	Renshaw et al., 2022	Psychology: an ecological dynamics approach to motor learning in practice	Reframing the learning and performing relationship in high-performance sport
21	M. A. Chen et al., 2021	Performance and technique	Effects of biofeedback
22	Aloui et al., 2021	Physical performance	Effects of elastic band plyometric training
23	Rohadi et al., 2021	Groundstroke forehand drive ability in novice tennis athletes	Effect of drill, foot position, and hand-eye coordination
24	Habay et al., 2021	Mental fatigue and sport-specific psychomotor performance	A systematic review

Table 2 (continued)

No	Author, Year	Physical Condition Variable	Training Type
25	Zacharakis et al., 2020	Balancing and technical skills in	Effect of balance and proprioceptive training
26	Kitamura et al., 2020	Skill performance	Strength and power training
27	Woods et al., 2020	Performance preparation models in contemporary high-level sport guided by an ecological dynamics framework	Theory to practice
28	Hammami et al., 2020	Physical performance	Effects of upper and lower limb plyometric training program on components
29	Vicente et al., 2020	Physical activity and tactical behaviour	Effects of 6 weeks of direct instruction and teaching games for understanding programs
30	Turna, 2020	Biomotor abilities	Effects of 6-week core training
31	Fardilha & Allen, 2020	Defining, assessing, and developing creativity in sport	A systematic narrative review
32	Wilkins et al., 2020	Insights, challenges, and accomplishments to guide future studies	An early review of stroboscopic visual training
33	K. Chen et al., 2019	Motor skill learning	Exercise training
34	Mohanta et al., 2019	Strength, speed, and agility	A comparative study circuit training and plyometric training
35	Zghal et al., 2019	Physical fitness	Combined resistance and plyometric training are more effective than plyometric training alone
36	Gantois et al., 2019	both anaerobic and aerobic fitness	Repeated sprint training
37	Payne et al., 2019	Anxiety-attention relationship in far-aiming skills	A systematic review
38	Hagan Jnr & Schack, 2019	Integrating pre-game rituals and pre-performance routines in a culture-specific context	Implications for sport psychology consultancy
39	Devonport et al., 2019	Identity among high performance	Examining the construction

to compare them (Shah, 2024). Rather, accomplishments should only be evaluated in relation to the skills of former competitors. According to S. Nugroho et al., (2021) the Circuit can be utilised during the first week of anatomical adaption. To determine the load for the primary movements, begin by assessing the athlete for RM 1 (Raj & Maniazhagu, 2022). Select circuit stations based on the requirements of the exercise regimen (Hu et al., 2024). Depending on the athlete's ability and training history, a specific progression plan needs to be followed (Ratajczak et al., 2024). Start with body weight exercises for novice exercisers who have never done any strength training (Themistocleous et al., 2021).

Strength Exercises

The most important factor that forms the foundation for other aspects of physical condition is strength. It is among the physical requirements for practically every sport (Balachandran et al., 2022). To catch trainers' attention, it is crucial to increase the strength component's capacity. According to the demands of each sport, strength is a component of physical condition that can be maximally developed (Ottinger et al., 2022). Sports games will not require the same level of strength as weightlifting (Schumann et al., 2022). The ability of muscles to exert maximal effort while doing continuous or repetitive labour against resistance is another definition of muscle strength (Suarez-Arrones & Loturco, 2022).

Training for Endurance

One of the key components of motor skills is endurance, which comes from students' psychological ability to support movement at a specific moment (Lucas et al., 2020). The capacity of muscles to continue moving during high-intensity or static exercise is known as muscular endurance (Huiberts et al., 2024). A condition that stresses the ability

to labour continuously in an aerobic environment is called endurance. The capacity to work for a prolonged amount of time without experiencing severe exhaustion is known as endurance (Prieto-Gonz, 2022). When it comes to working muscles, endurance is the capacity to operate a muscle or group of muscles in a specific amount of time, whereas the energy system is the body's ability to function its organs in a specific amount of time (Düking et al., 2021).

Training in Kinesthetics' Perception

In order to improve a fencer's performance of fencing techniques and her awareness of all the variables surrounding her during the technical performance, kinesthetics' perception is a crucial and necessary component of the sport (Tinaz et al., 2022). During an attack, defences, response, and counter movement's, make the right choice regarding the proper kinetic response (Mashkoo & Hameed, 2022). When a person's senses are stimulated, their body or certain body parts move concurrently, a phenomenon known as kinesthetics' perception occurs (Latash, 2024). Therefore, because the five senses are more accurate at controlling movement, feelings can provide information about the position of the body or body parts so that they move further (Wuang & Huang, 2022). According to Peng et al., (2023), this suggests that the human body has the ability to sense and maintain its position in order to control movements or decide how much muscle work will be done consciously. As a result, the activities that are produced involve a lot of calculations and can eventually be performed in a time-sensitive manner and turn into motion automation.

Perception of different modalities is known to be dependent on a continuing action-related efferent process (Latash, 2024). Kinesthetics' sense, also known as kinesthetics' per-

ception, refers to sensory input that takes place within the body (Wuang et al., 2021). By extending the body's muscles, the sensory system receives information about movement and posture. The kinesthetics' senses are capable of tracking the body's position even while it is still. Accordingly, the human body's organs that are directly connected to movement have a role in the kinesthetics' sense (Kumari et al., 2023). The capacity to take in the postures and movements of the body as well as its components provides a more practical grasp of kinesthetics' awareness (Fritz et al., 2022). A sensation known as kinesthetics' perception is brought on by activation of muscle receptors, muscle fascia, tendons, and joints. These structures serve as a feedback mechanism, allowing an individual to perceive their body's position or specific body parts in order to control movements more precisely or accurately.

Sport of Shadow Training

Shadow workouts, often known as shadow steps, are foot movements that reposition the body to facilitate players' hitting motions (Ihsan et al., 2024). Because there are numerous ways to practise the shadow exercise method, it can be used to train leg motions (Ishak et al., 2020). Badminton players are advised to perform shadow workouts since they can improve their balance, agility, and quickness (Babar et al., 2021). Practise taking shadow steps to the court's corners as part of the Shadow Exercise, which is a footstep action that helps players position their bodies to make hitting moves simpler (Pratama et al., 2024).

Training using Rope Balls

Even in the absence of a coach or opponent, a rope tennis ball, also known as a bottle, can be used for court tennis practice. Training against a wall is nearly identical to this (Agustiyanta, Hidayatullah et al., 2022). A string tennis ball is referred to by its initials, "Boteli," and it has free ball brand specifications as long as it is as good as the elastic rope's length, or about 4 metres. The rope tennis ball assist is a tennis ball with a hole punched in it, linked with an elastic rubber strap that is incredibly strong, and tied with a plastic base that is weighted to withstand the ball's speed. Efficiency and functionality are two advantages of using a string tennis ball for technical drills like Relly Groundstroke. Even in the absence of a coach or opponent, a rope tennis ball, also known as a bottle, can be used for court tennis practice. It is quite similar to training with a wall. The Rope Tennis Ball is different in that it employs a rope that is attached to the ball and has its other end fastened to a brick or other weighted object. The player stands directly at the end of the rope, close to the weight, and hits the ball from this position to use it. After striking the ground, the ball rebounds off the corner. The ball spins in the direction of the player when it reaches the conclusion. When the ball was returned, the player enjoyed being hit again right away. It is repeated until the desired outcome is achieved. It is anticipated that this ball will be used so that court tennis instruction can take place anywhere, even on calm, paved streets.

Interval Training

A form of cardiovascular exercise known as interval training is repeated high-intensity training during a brief training period (Parmar et al., 2021). The goal of this exercise is to enhance training intensity in a little amount of

time by alternating short rest intervals with high-intensity exercise sessions (Szumilewicz & Santos-Rocha, 2022). Interval training, often known as interval training, is a kind of aerobic exercise that is frequently done at a high intensity for brief periods of time (Fennell & Hopker, 2021). To build strength and raise the exercise's intensity, training periods can be progressively followed by heavier training motions (Yin et al., 2024). An intense series of quick, high-intensity workouts alternated with simpler, slower activities is known as interval training (Yin et al., 2024). Another name for this workout is "Fartlek," which is Swedish for "speed play." Instead of requiring you to train constantly, Fartlek raises the intensity of your workouts so you can perform more exercises (Brondani et al., 2022). Interval training was designed in a more systematic manner to enhance physical fitness. Training intervals alternate between active and resting times.

Exercise Frequency

In many scenarios where individual players must acquire (or relearn) motor skills, time is a critical limitation (Schmidt, 2019). The frequency of the time restriction for skill training is this circumstance. To optimise the quantity of possible learning, the frequency must be controlled (Maxime et al., 2024). Instructors must be aware of the variables, or practice settings, that affect learning success in order to meet the needs of frequency and make adjustments to maximise learning (Chester et al., 2024). For individual tennis players, frequency is an important factor to take into account. Even with just two practice sessions per week, beginners can get better (Nair et al., 2024). One of the most important aspects of a training programme is rest; getting enough of it will boost output and lower the chance of injury (Murphy et al., 2022). A three-minute rest is given by players to replenish energy following a brief workout (e.g., 10 to 60 seconds of activity). When designing a training regimen based on the evolution of the energy system, players must take this into consideration. A player experiences exhaustion when they run as fast as they can for ninety seconds; this is known as metabolic fatigue, which affects the energy system, thus they need enough rest time to recover.

Conclusions

After a thorough analysis, it was discovered that there is a relationship between physical performance and training methods and how well field tennis drive stroke skills are improved. Physical performance includes things like muscle strength, aerobic and anaerobic endurance, speed and acceleration, explosiveness, flexibility, agility, and balance. Training methods include circuit training, strength training, endurance training, kinesthetics' perception training, shadow sports training, rope ball.

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Conflict of interest

The researcher states that there are no conflicts of interest in this work.

References

- Amni, H., & Sulaiman, I. (2019). Model Latihan Keterampilan Groundstroke Pada Cabang Olahraga Tennis Lapangan. *Jurnal Terapan Ilmu Keolahragaan*, 4(2), 91-98. <https://doi.org/10.17509/jtikor.v4i2.18968>
- Soegiyanto, Z. A., & Nugroho, P. (2012). Pengaruh Variasi Latihan Forehand Drive Terhadap Kemampuan Melakukan Forehand Drive Tennis Lapangan Bagi Petenis Pemula. *Journal of Sport Sciences and Fitness*, 1(2), 32-40.
- Tegar Prastawa, Wimba, Hadi Husnul, Dwi Pradipta, G. (2022). Pengaruh Latihan Feeding Terhadap Hasil Pukulan Forehand Drive Dan Backhand Drive Tennis Lapangan. *Journal of Physical Activity and Sports*, 3(April), 1-8. <https://doi.org/10.53869/jpas.v3i1.115>
- Kolman, N. S., Kramer, T., Elferink-gemser, M. T., Barbara, C. H., Visscher, C., Kolman, N. S., Kramer, T., & Elferink-gemser, M. T. (2019). Technical and tactical skills related to performance levels in tennis : A systematic review. *Journal of Sports Sciences*, 37(1), 108-121. <https://doi.org/10.1080/02640414.2018.1483699>
- Fauzi, D., Hanif, A. S., & Siregar, N. M. (2021). The effect of a game-based mini tennis training model on improving the skills of groundstroke forehand drive tennis. *Journal of Physical Education and Sport*, 21(4), 2325-2331. <https://doi.org/10.7752/jpes.2021.s4311>
- Jariono, G., Nugroho, H., Nugroho, D., Nyatara, S. D., Marganingrum, T., & Setiawati, D. (2021). Determining Factors Of Jump Service Volleyball In The Student Activity Unit Of Volleyball. *Kinestetik: Jurnal Ilmiah Pendidikan Jasmani*, 5(4), 799-808. <https://doi.org/10.33369/jk.v5i4.19771>
- Jariono, G., Nurhidayat, N., & Indarto, P. (2024). Physical Activity Training Methods to Improve the Physical Condition of Volleyball Players: A Systematic Review. *Physical Education Theory and Methodology*, 24(1), 118-129. <https://doi.org/10.17309/tmfv.2024.1.15>
- Nugroho, H., Gontara, S. Y., Angga, P. D., Jariono, G., & Maghribi, I. L. (2021). Quality Of Physical Condition Of Youth Pencak Silat Athletes Reviewed From Speed, Power, and Strength. *Kinestetik: Jurnal Ilmiah Pendidikan Jasmani*, 5(1), 154-162. <https://doi.org/10.33369/jk.v5i1.14376>
- Bompa, T. O., & Buzzichelli, C. A. (2019). Periodization: Theory and Methodology of Training. *Journal of Chemical Information and Modeling*, 53(9). <https://doi.org/10.5040/9781718225435>
- Anderson, E., Stone, J. A., & Dunn, M. (2021). Coach approaches to practice design in performance tennis. *International Journal of Sport Science & Coaching*, 16(6), 1281-1292. <https://doi.org/10.1177/17479541211027294>
- Amico, G., & Schaefer, S. (2022). Tennis expertise reduces costs in cognition but not in motor skills in a cognitive-motor dual-task condition. *Acta Psychologica*, 223(January), 103503. <https://doi.org/10.1016/j.actpsy.2022.103503>
- Dohme, L.-C., Bloom, G. A., Piggott, D., & Backhouse, S. (2020). Development, Implementation, and Evaluation of an Athlete-Informed Mental Skills Training Program for Elite Youth Tennis Players. *Journal of Applied Sport Psychology*, 32(5), 429-449. <https://doi.org/10.1080/10413200.2019.1573204>
- Faber, I. R., Koopmann, T., & Büsch, D. (2021). Developing a tool to assess technical skills in talented youth table tennis players — a multi-method approach combining professional and scientific literature and coaches' perspectives. *Springer*, 7(42), 1-24. <https://doi.org/10.1186/s40798-021-00327-5>
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., ... Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *The BMJ*, 372. <https://doi.org/10.1136/bmj.n71>
- Cashin, A. G., & McAuley, J. H. (2020). Clinimetrics: Physiotherapy Evidence Database (PEDro) Scale. *Journal of Physiotherapy*, 66(1), 59. <https://doi.org/10.1016/j.jphys.2019.08.005>
- Moseley, A. M., Elkins, M. R., Van der Wees, P. J., & Pinheiro, M. B. (2020). Using research to guide practice: The Physiotherapy Evidence Database (PEDro). *Brazilian Journal of Physical Therapy*, 24(5), 384-391. <https://doi.org/10.1016/j.bjpt.2019.11.002>
- Sharma, A., Prasad, B. K., Das, R., Sharma, A., Karmakar, D., & Choudhary, P. K. (2024). Analyzing the Impact of VMBR Training on Table Tennis Players' Competence in Performing Alternate Counter and Forehand Drive Shots With Precision. *Physical Education Theory and Methodology*, 24(3), 382-387. <https://doi.org/10.17309/tmfv.2024.3.05>
- Shuzhen Ma, Soh, K. G., Japar, S. B., Liu, C., Luo, S., Mai, Y., Wang, X., & Zhai, M. (2024). Effect of core strength training on the badminton player's performance : A systematic review & meta-analysis. *PLoS ONE*, 1-22. <https://doi.org/10.1371/journal.pone.0305116>
- Zhang, Y. (2024). The optimization of college tennis training and teaching under deep learning. *Heliyon*, 10(4), e25954. <https://doi.org/10.1016/j.heliyon.2024.e25954>
- Williams, B. K., Sanders, R. H., Ryu, J. H., Graham-Smith, P., & Sinclair, P. J. (2024). Racket orientation angle differences between accurate and inaccurate squash shots, as determined by a racket embedded magnetic-inertial measurement unit. *Sports Biomechanics*, 23(6), 817-829. <https://doi.org/10.1080/14763141.2021.1892175>
- Williamson, S., Arden, C. L., Berry, C., Heron, N., Janse, D. C., & Marleen, V. R. (2024). The Physical Demands of Wheelchair Tennis Match Play : A Systematic Review with Meta - analysis. *Sports Medicine*, 54(5). <https://doi.org/10.1007/s40279-024-02028-x>
- Büttner, C. M., Kennemich, C., & Williams, K. D. (2024). The power of human touch : Physical contact improves performance in basketball free throws. *Psychology of Sport & Exercise*, 72(February), 102610. <https://doi.org/10.1016/j.psychsport.2024.102610>
- Kumar, S., & Das, R. (2024). Championing Olympic Excellence: A Bibliometric Analysis of Biomechanics Impacting Tennis Performance on the World Stage. *Physical Education Theory and Methodology*, 24(3), 494-503. <https://doi.org/10.17309/tmfv.2024.3.20>
- Nugroho, D., Hidayatullah, M. F., Doewes, M., & Purnama, S. K. (2023). The effects of massed and distributed drills, muscle strength, and intelligence quotients towards tennis groundstroke skills of sport students. *Pedagogy of Physical Culture and Sports*, 27(1), 14-23. <https://doi.org/10.15561/26649837.2023.0102>
- Kaplan, A. (2023). The effect of 12 weeks of tennis education on accuracy performance Tennis. *Journal of ROL Sport*

- Sciences, Special Is*(1), 290-300.
<https://doi.org/10.5281/zenodo.10027724>
- Wood, D., Reid, M., Elliot, B., Alderson, J., Mian, A., Wood, D., Reid, M., Elliot, B., Alderson, J., & Wood, D. (2023). The expert eye? An inter-rater comparison of elite tennis serve kinematics and performance. *Journal of Sports Sciences*, 41(19), 1779-1786.
<https://doi.org/10.1080/02640414.2023.2298102>
- Díaz-García, J., García-Calvo, T., Manzano-Rodríguez, D., López-Gajardo, M. Á., Alberto, J., & Ring, C. (2023). Brain endurance training improves shot speed and accuracy in grassroots padel players. *Journal of Science and Medicine in Sport*, 26(7), 386-393.
<https://doi.org/10.1016/j.jsams.2023.06.002>
- Irawan, R., Azam, M., Rahayu, S., Setyawati, H., Adi, S., Priyono, B., & Nugroho, A. (2023). Biomechanical Motion of The Tennis Forehand Stroke: Analyzing the Impact on The Ball Speed Using Biofor Analysis Software. *Physical Education Theory and Methodology*, 23(6), 918-924. <https://doi.org/10.17309/tmfv.2023.6.14>
- Rodríguez-Perea, A. Á., Reyes-Ferrada, W., & Jerez-Mayorga, D. (2023). Core training and performance : a systematic review with meta-analysis. *Biology of Sport*, 40(4), 975-992. <https://doi.org/10.5114/biolsport.2023.123319>
- Deng, N., Soh, K. G., Huang, D., Abdullah, B., Luo, S., & Rattanakoses, W. (2022). Effects of plyometric training on skill and physical performance in healthy tennis players: A systematic review and. *Frontiers in Phychiatry*, 13(November), 1-16.
<https://doi.org/10.3389/fphys.2022.1024418>
- Colomar, J., Corbi, F., Brich, Q., & Baiget, E. (2022). Determinant Physical Factors of Tennis Serve Velocity: A Brief Review. *Human Kinetics*, 17(8), 1159-1169.
<https://doi.org/10.1123/ijsp.2022-0091>
- Rusdiana, A., Razali, M., Abdullah, B. I. N., & Syahid, A. M. (2022). Original Article Backhand drive stroke technique in tennis: 3D biomechanical analysis approach. *Journal of Physical Education and Sport*, 22(11), 2826-2832.
<https://doi.org/10.7752/jpes.2022.11358>
- James, M., Craig, F., Bridge, A., Greig, M., Michael, R., & Finlay, M. J. (2022). Upper - Body Post - activation Performance Enhancement for Athletic Performance : A Systematic Review with Meta - analysis and Recommendations for Future Research. *Sports Medicine*, 52(4), 847-871.
<https://doi.org/10.1007/s40279-021-01598-4>
- Saeterbakken, A. H., Stien, N., Andersen, V., Scott, S., & Cumming, K. T. (2022). The Effects of Trunk Muscle Training on Physical Fitness and Sport - Specific Performance in Young and Adult Athletes: A Systematic Review and Meta - Analysis. *Sports Medicine*, 52(7), 1599-1622. <https://doi.org/10.1007/s40279-021-01637-0>
- Renshaw, I., Davids, K., Sullivan, M. O., Maloney, M. A., Crowther, R., & Mccosker, C. (2022). Psychology An ecological dynamics approach to motor learning in practice : Reframing the learning and performing relationship in high performance sport. *Asian Journal of Sport and Exercise Psychology*, 2(1), 18-26.
<https://doi.org/10.1016/j.ajsep.2022.04.003>
- Chen, M. A., Spanton, K., Schaik, P. Van, & Spears, I. (2021). The Effects of Biofeedback on Performance and Technique of the Boxing Jab. *Sage Journal: Perceptual and Motor Skills*, 128(4), 1607-1622.
<https://doi.org/10.1177/00315125211013251>
- Aloui, G., Hermassi, S., Hayes, L. D., Shephard, R. J., Chelly, M. S., & Schwesig, R. (2021). Effects of Elastic Band Plyometric Training on Physical Performance of Team Handball Players. *Applied Sciences*, 11(3), 1-13.
<https://doi.org/10.3390/app11031309>
- Rohadi, M., Rahayu, S., & Hartono, M. (2021). Effect of Drill , Foot Position , and Hand-Eye Coordination on Groundstroke Forehand Drive Ability in Novice Tennis Athletes. *Journal of Hunan University (Natural Sciences)*, 48(5), 173-179.
- Habay, J., Cutsem, J. Van, Verschueren, J., Bock, S. De, & Proost, M. (2021). Mental Fatigue and Sport - Specific Psychomotor Performance: A Systematic Review. *Sports Medicine*, 51(7), 1527-1548.
<https://doi.org/10.1007/s40279-021-01429-6>
- Zacharakis, E. D., Bourdas, D. I., Kotsifa, M. I., & Evangelos, M. (2020). Effect of balance and proprioceptive training on balancing and technical skills in 13-14-year-old youth basketball players. *Journal of Physical Education and Sport*, 20(5), 2487-2500.
<https://doi.org/10.7752/jpes.2020.05340>
- Kitamura, K., Roschel, H., Loturco, I., Lamas, L., Tricoli, V., João, P. V., Fellingham, G., & Ugrinowitsch, C. (2020). Strength and power training improve skill performance in volleyball players. *Motriz: Revista de Educação Física: SciELO Brasil*, 26(1), 1-9.
<https://doi.org/10.1590/s1980-65742020000110200034>
- Woods, C. T., Mckeown, I., Sullivan, M. O., Robertson, S., & Davids, K. (2020). Theory to Practice : Performance Preparation Models in Contemporary High-Level Sport Guided by an Ecological Dynamics Framework. *Sports Medicine*, 6(36), 1-11.
<https://doi.org/10.1186/s40798-020-00268-5>
- Hammami, M., Gaamouri, N., Suzuki, K., & Shephard, R. J. (2020). Effects of Upper and Lower Limb Plyometric Training Program on Components of Physical Performance in Young Female Handball Players. *Frontiers in Physiology*, 11(August), 1-10.
<https://doi.org/10.3389/fphys.2020.01028>
- Vicente, J., Clemente, F. M., Rey, E., & Gonz, S. (2020). Effects of 6 Weeks Direct Instruction and Teaching Games for Understanding Programs on Physical Activity and Tactical Behaviour in U-12 Soccer Players. *International Journal of Environmental Research and Public Health*, 17(14). <https://doi.org/10.3390/ijerph17145008>
- Turna, B. (2020). The Effects of 6-Week Core Training on Selected Biomotor Abilities in Soccer Players. *Journal of Education and Learning*, 9(1), 99-109.
<https://doi.org/10.5539/jel.v9n1p99>
- Fardilha, F. de S., & Allen, J. B. (2020). Defining, assessing, and developing creativity in sport: a systematic narrative review. *International Review of Sport and Exercise Psychology*, 13(1), 104-127.
<https://doi.org/10.1080/1750984X.2019.1616315>
- Wilkins, L., & Appelbaum, L. G. (2020). An early review of stroboscopic visual training: Insights, challenges and accomplishments to guide future studies. *International Review of Sport and Exercise Psychology*, 13(1), 65-80.
<https://doi.org/10.1080/1750984X.2019.1582081>
- Chen, K., Zheng, Y., Wei, J., Ouyang, H., Huang, X., Zhang, F., Sau, C., Lai, W., Ren, C., So, K., & Zhang, L. (2019). Exercise training improves motor skill learning via selective activation of mTOR. *Science Advances*, 5(7), 1-11. <https://doi.org/10.1126/sciadv.aaw1888>
- Mohanta, N., Kalra, S., & Pawaria, S. (2019). A Comparative Study of Circuit Training and Plyometric Training on Strength , Speed and Agility in State Level Lawn Tennis

- Players. *Journal of Clinical and Diagnostic Research*, 13(2), 5-10. <https://doi.org/10.7860/JCDR/2019/42431.13348>
- Zghal, F., Colson, S. S., Blain, G., Behm, D. G., Granacher, U., & Chaouachi, A. (2019). Combined resistance and plyometric training is more effective than plyometric training alone for improving physical fitness of pubertal soccer players. *Frontiers in Physiology*, 10(AUG), 1-11. <https://doi.org/10.3389/fphys.2019.01026>
- Gantois, P., Batista, G. R., Aidar, F. J., Nakamura, F. Y., De Lima-Júnior, D., Cirilo-Sousa, M. S., De Matos, D. G., & Cabral, B. G. A. T. (2019). Repeated sprint training improves both anaerobic and aerobic fitness in basketball players. *Isokinetics and Exercise Science*, 27(2), 97-105. <https://doi.org/10.3233/IES-182212>
- Payne, K. L., Wilson, M. R., & Vine, S. J. (2019). A systematic review of the anxiety-attention relationship in far-aiming skills. *International Review of Sport and Exercise Psychology*, 12(1), 325-355. <https://doi.org/10.1080/1750984X.2018.1499796>
- Hagan Jnr, J. E., & Schack, T. (2019). Integrating pre-game rituals and pre-performance routines in a culture-specific context: Implications for sport psychology consultancy. *International Journal of Sport and Exercise Psychology*, 17(1), 18-31. <https://doi.org/10.1080/1612197X.2017.1292301>
- Devonport, T. J., Leflay, K., & Russell, K. (2019). Examining the construction of identity among high performance male and female athletes using photography. *Qualitative Research in Sport, Exercise and Health*, 11(5), 720-739. <https://doi.org/10.1080/2159676X.2019.1614973>
- Annasai, F., Nugroho, S., Hartanto, A., & Arianto, A. C. (2023). Circuit training based physical condition training model to increase speed, agility, arm power, and limb muscle power of basketball athletes. *Pedagogy of Physical Culture and Sports*, 27(4), 282-288. <https://doi.org/10.15561/26649837.2023.0403>
- Yulianto, W. D., & Yudhistira, D. (2021). Content Validity of Circuit Training Program and Its Effects on The Aerobic Endurance of Wheelchair Tennis Athletes. *International Journal of Kinesiology & Sports Science*, 9(3), 60-65. <https://doi.org/10.7575/aiac.ijkss>
- Bompa, T. O., & Buzzichelli, C. (2018). *Periodization-6th Edition: Theory and Methodology of Training*. In Human Kinetics. <https://doi.org/10.5040/9781718225435>
- Shah, D. (2024). A Comparative Study Of Plyometric And Circuit Training On Agility And Strength In Badminton Players: An Experimental Study. *Educational Administration: Theory and Practice*, 30(4), 8369-8381. <https://doi.org/10.53555/kuey.v30i4.2732>
- Nugroho, S., Nasrulloh, A., Karyono, T. H., Dwihandaka, R., & Pratama, K. W. (2021). Effect of intensity and interval levels of trapping circuit training on the physical condition of badminton players. *Journal of Physical Education and Sport*, 21(3), 1981-1987. <https://doi.org/10.7752/jpes.2021.s3252>
- Raj, D. S. L., & Maniazhagu, D. D. (2022). Effect of Circuit Training Combined with Speed Agility Quickness Drills and Jump Rope Drills on Upperbody Muscular Endurance. *Journal of Advances in Sports and Physical Education*, 5(2), 24-30. <https://doi.org/10.36348/jaspe.2022.v05i02.003>
- Hu, C., Xia, Y., Zeng, D., Ye, M., & Mei, T. (2024). Effect of resistance circuit training on comprehensive health indicators in older adults : a systematic review and meta-analysis. *Scientific Reports*, 1-11. <https://doi.org/10.1038/s41598-024-59386-9>
- Ratajczak, M., Krzywicka, M., Szulińska, M., Musiałowska, D., Kusy, K., & Karolkiewicz, J. (2024). Effects of 12-Week Combined Strength and Endurance Circuit Training Program on Insulin Sensitivity and Retinol-Binding Protein 4 in Women with Insulin-Resistance and Overweight or Mild Obesity: A Randomized Controlled Trial. *Diabetes, Metabolic Syndrome and Obesity*, 17, 93-106. <https://doi.org/10.2147/DMSO.S432954>
- Themistocleous, I., Agathangelou, P., & Stefanakis, M. (2021). Sports and Exercise Medicine Effects of Moderate-Intensity Intermittent Circuit Training in Obese and Overweight Individuals. *International Journal of Sports and Exercise Medicine*, 7(3). <https://doi.org/10.23937/2469-5718/1510194>
- Balachandran, A. T., Steele, J., Angielczyk, D., Belio, M., Schoenfeld, B. J., & Quiles, N. (2022). Comparison of Power Training vs Traditional Strength Training on Physical Function in Older Adults A Systematic Review and Meta-analysis. *JAMA Network*, 5(5), 1-14. <https://doi.org/10.1001/jamanetworkopen.2022.11623>
- Ottinger, C. R., Sharp, M. H., Stefan, M. W., Gheith, R. H., & Espriella, F. De. (2022). Muscle Hypertrophy Response to Range of Motion in Strength Training : A Novel Approach to Understanding the Findings. *Strength and Conditioning Journal*, 45(May 2023), 162-176. <https://doi.org/10.1519/SSC.0000000000000737>
- Schumann, M., Feuerbacher, J. F., Sünkeler, M., Freitag, N., Rønnestad, B. R., & Doma, K. (2022). Compatibility of Concurrent Aerobic and Strength Training for Skeletal Muscle Size and Function: An Updated Systematic Review and Meta - Analysis. *Sports Medicine*, 52(3), 601-612. <https://doi.org/10.1007/s40279-021-01587-7>
- Suarez-Arrones, L., & Loturco, I. (2022). Strength Training in Professional Soccer: Effects on Short-sprint and Jump Performance. *International Journal of Sports Medicine*, 43. <https://doi.org/10.1055/a-1653-7350>
- Lucas, S., Dallaway, N., Lucas, S. J. E., & Ring, C. (2020). Concurrent brain endurance training improves endurance exercise performance. *Journal of Science and Medicine in Sport*, October. <https://doi.org/10.1016/j.jsams.2020.10.008>
- Huiberts, R. O., Wüst, R. C. I., & Zwaard, S. Van Der. (2024). Concurrent Strength and Endurance Training : A Systematic Review and Meta - Analysis on the Impact of Sex and Training Status. *Sports Medicine*, 54(2), 485-503. <https://doi.org/10.1007/s40279-023-01943-9>
- Prieto-Gonz, P. (2022). Effects of Running-Specific Strength Training, Endurance Training, and Concurrent Training on Recreational Endurance Athletes' Performance and Selected Anthropometric Parameters. *International Journal of Environmental Research and Public Health*, 19(7), 1-17. <https://doi.org/10.3390/ijerph191710773>
- Düking, P., Zinner, C., Trabelsi, K., Reed, J. L., Holmberg, H., Kunz, P., & Sperlich, B. (2021). Monitoring and adapting endurance training on the basis of heart rate variability monitored by wearable technologies: A systematic review with meta-analysis. *Journal of Science and Medicine in Sport*, 24, 1180-1192. <https://doi.org/10.1016/j.jsams.2021.04.012>
- Tinaz, S., Kamel, S., Aravala, S. S., Elfil, M., Bayoumi, A., Patel, A., Scheinost, D., Sinha, R., & Hampson, M. (2022). NeuroImage: Clinical Neurofeedback-guided kinesthetics' motor imagery training in Parkinson'

- s disease: Randomized trial. *NeuroImage: Clinical*, 34(October 2021), 102980.
<https://doi.org/10.1016/j.nicl.2022.102980>
- Mashkoo, N. B., & Hameed, N. H. (2022). Effect of physical-kinesthetics' intelligence exercises on developing motor abilities and basic skills of basketball in female students. *SPORT TK-EuroAmerican Journal of Sport Sciences*, 11, 1-10. <https://doi.org/10.6018/sportk.514981>
- Latash, M. L. (2024). Efference copy in kinesthetics' perception: a copy of what is it? *JNP: Journal of Neurophysiology*, 125(4), 1079-1094.
<https://doi.org/10.1152/jn.00545.2020>
- Wuang, Y., & Huang, C. (2022). Haptic Perception Training Programs on Fine Motor Control in Adolescents with Developmental Coordination Disorder: A Preliminary Study. *Journal of Clinical Medicine*, 11(16).
<https://doi.org/10.3390/jcm11164755>
- Peng, Y., Sakai, Y., Nakagawa, K., Funabara, Y., & Aoyama, T. (2023). Funabot-Suit: A bio-inspired and McKibben muscle-actuated suit for natural kinesthetics' perception. *Biomimetic Intelligence and Robotics*, 3(4), 100127.
<https://doi.org/10.1016/j.birob.2023.100127>
- Wuang, Y., Chen, Y. J., Chiu, Y., Wang, C., Chen, C., Huang, C., Wu, T., Hsieh, T., & Ho, W. (2021). Effectiveness of Kinesthetics' Game-Based Training System in Children With Visual-Perceptual Dysfunction. *IEEE Access*, 9, 153838-153849.
<https://doi.org/10.1109/ACCESS.2021.3128109>
- Kumari, R., Lee, S., Shin, J., & Lee, S. (2023). Effect of Perceptual Training with Sound-Guided and Kinesthetics' Feedback on Human 3D Sound Localization Capabilities. *Sensors*, 23(11), 1-15. <https://doi.org/10.3390/s23115023>
- Fritz, J., Athmann, M., Bornhütter, R., Buscher, N., Geier, U., Mergardt, G., Scherr, C., & Doesburg, P. (2022). Analytical perception and kinesthetics' engagement in evaluation of copper chloride crystallization patterns of wheat, grape juice and rocket samples from conventional, organic and biodynamic cultivation. *Chemical and Biological Technologies in Agriculture*, 1-20.
<https://doi.org/10.1186/s40538-022-00361-9>
- Ihsan, F., Nasrullo, A., Nugroho, S., & Yuniana, R. (2024). The Effect of Shadow Training and Muscle Endurance on Agility of Badminton Athletes 12-17 Years of Age El efecto del entrenamiento en sombra y la resistencia muscular en la agilidad de los atletas de bádminton de 12 a 17 años de edad. *Retos: Nuevas Tendencias En Educación Física, Deporte y Recreación*, 54, 36-45.
<https://dialnet.unirioja.es/servlet/articulo?codigo=9319647>
- Ishak, M., Sofyan, A., Firmansyah, H., & Herman, D. (2020). The Effect of the Shadow Training Model on VO₂ max Ability in Badminton Game. *Atlantis Press: Advances in Social Science, Education and Humanities Research*, 481(Icest 2019), 241-244.
<https://doi.org/10.2991/assehr.k.201027.050>
- Babar, F., Farhan Tabassum, M., Sattar, S., ul An Babar, N., Hassan, S., & Karim, R. (2021). Analysis Of Table Tennis Skills: An Assessment Of Shadow Practice In Learning Forehand And Backhand Drive. *Palarch's Journal Of Archaeology Of Egypt/Egyptology*, 18(8), 4488-4502.
- Pratama, A. P., Sukamti, E. R., Suhartini, B., Sulistiyowati, E. M., Sepdanius, E., Ayubi, N., Ndayisenga, J., & Sibomana, A. (2024). Effects of Shadow Training and Leg Muscle Strength on Badminton Footwork Agility: A Factorial Experimental Design Efectos del Entrenamiento de Sombras y la Fuerza Muscular de las Piernas en la Agilidad del Juego de Piernas de Bádminton: Un diseño experime. *Retos: Nuevas Tendencias En Educación Física, Deporte y Recreación*, 54, 207-215.
<https://doi.org/10.47197/retos.v54.103303>
- Agustiyanta, Hidayatullah, M. F., Doewes, M., & Purnama, S. K. (2022). BOTELI and Interval Training to Improve Tennis Groundstroke Forehand's Rally Skills. *International Journal of Human Movement and Sports Sciences*, 10(6), 1311-1317.
<https://doi.org/10.13189/saj.2022.100622>
- Parmar, A., Jones, T. W., & Hayes, P. R. (2021). The dose-response relationship between interval-training and VO₂ max in well-trained endurance runners: A systematic review. *Journal of Sports Sciences*, 39(12), 1410-1427.
<https://doi.org/10.1080/02640414.2021.1876313>
- Szumilewicz, A., & Santos-Rocha, R. (2022). How to HIIT while pregnant? The protocol characteristics and effects of high intensity interval training implemented during pregnancy – A systematic review. *Baltic Journal Of Health and Physical Activity*, 14(1), 1-16.
<https://doi.org/10.29359/BJHPA.14.1.01>
- Fennell, C. R. J., & Hopker, J. G. (2021). The acute physiological and perceptual effects of recovery interval intensity during cycling - based high - intensity interval training. *European Journal of Applied Physiology*, 121(2), 425-434. <https://doi.org/10.1007/s00421-020-04535-x>
- Yin, M., Li, H., Bai, M., Liu, H., Chen, Z., Deng, J., Deng, S., Meng, C., Vollaard, N. B. J., Little, J. P., & Li, Y. (2024). Is low-volume high-intensity interval training a time-efficient strategy to improve cardiometabolic health and body composition? A meta-analysis. *Applied Physiology, Nutrition, and Metabolism*, 49(3), 273-292.
<https://doi.org/10.1139/apnm-2023-0329>
- Brondani, M., Mello, D., Camponogara, N., Barreto, F., & Ulisses, L. (2022). ScienceDirect Effect of high-intensity interval training protocols on VO₂ max and HbA1c level in people with type 2 diabetes : A systematic review and meta- analysis. *Annals of Physical and Rehabilitation Medicine*, 65(5).
<https://doi.org/10.1016/j.rehab.2021.101586>
- Schmidt, R. A. (2019). *Motor Control and Learning A* (Sixth Edit). Human kinetics.
- Maxime, P. S., Maire, L., Heusinger, T., Klein, J., & Labinsky, H. (2024). The exercise-app Axia for axial spondyloarthritis enhances the home- based exercise frequency in axial spondyloarthritis patients – A cross-sectional survey. *Rheumatology International*, 44, 1143-1154.
<https://doi.org/10.1007/s00296-024-05600-w>
- Chester, R., Khondoker, M., Jerosch-Herold, C., Lewis, J., Gurney, C., & Shepstone, L. (2024). Musculoskeletal shoulder pain: Home exercise frequency and adherence to appointments are not mediators of outcome. *Journal of Bodywork & Movement Therapies*, 40(April), 153-160.
<https://doi.org/10.1016/j.jbmt.2024.03.074>
- Nair, D., Schildcrout, J. S., Prigmore, H. L., Greevy, R., Trochez, R. J., Bachmann, J. M., Umeukeje, E. M., Fissell, R. B., Taylor, W. D., Kripalani, S., & Cavanaugh, K. L. (2024). Health Competence Is a Determinant of Exercise Frequency in Older Adults With CKD. *Kidney International Reports*, 1-4.
<https://doi.org/10.1016/j.ekir.2024.05.026>
- Murphy, J., Sweeney, M. R., & McGrane, B. (2022). The effect of a games-based intervention on wellbeing in adolescent girls. *Health Education Journal*, 81(4), 463-478.
<https://doi.org/10.1177/00178969221090583>

Оцінка впливу тренувальних методик та фізичної результативності на розвиток навичок з техніки виконання драйву в корт-тенісі: Огляд літератури

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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., 94 джерел.

Мета дослідження. Метою дослідження було розробити програму тренувань та покращити показники фізичної результативності шляхом аналізу літературних джерел задля вдосконалення техніки виконання драйву (англ. "Drive" – сильний і низький удар при відбиванні м'яча) в цьому різновиді тенісу.

Матеріали та методи. Проведено комплексний аналіз попередніх досліджень, що включає огляд статей, опублікованих у період з 2019 по 2024 роки, в яких обговорюються шляхи поліпшення фізичної підготовленості волейболістів. Електронний пошук проводився з використанням наукометричних баз даних SPORTDiscus, PubMed, Google Scholar, Web of Science та Scopus. На наступному етапі дослідження було зібрано наукові статті, в яких розглядаються найефективніші способи покращення навичок з техніки виконання драйву в корт-тенісі за допомогою фізичної результативності та застосуванню практичних тренувальних методик.

Результати. Згідно з результатами цього дослідження було встановлено, що в сорока статтях використовувалися методи розвитку фізичної результативності та практики з метою покращення техніки виконання драйву в корт-тенісі. На основі оцінок фізичного стану та його подальшого покращення, матеріали було класифіковано за категоріями. Анаеробна швидкісна витривалість визначалася як метод тренування, який може бути застосований спортсменом.

Висновки. Після проведення ретельного аналізу було зроблено наступні висновки: оскільки фізична результативність включає м'язову силу, аеробну та анаеробну витривалість, швидкість і прискорення, вибухову силу, гнучкість, спритність і рівновагу, низка тренувальних режимів виявилася ефективною з точки зору вдосконалення навичок з техніки виконання драйву в корт-тенісі. До таких тренувальних методів належать кругові тренування, силові тренування, тренування на витривалість, тренування на розвиток кінестетичного сприйняття, тренування, що спрямовані на вивчення і засвоєння технічних елементів (наприклад, ударів) без залучення реального партнера, тренування з мотузковим м'ячем, інтервальні тренування та частота тренувань.

Ключові слова: огляд літератури, режими фізичних вправ, фізичний стан, виконання драйву, корт-теніс.

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REVIEW ARTICLE

Physical Exercise Increases Cardiac Troponin (cTn) Levels as a Marker of Myocardial Infarction: A Systematic Review

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Abstract

Objectives. This study aimed to analyze an indication of physical exercise on the increase of cardiac troponin (cTn) levels as a marker of myocardial infarction from the physiological perspective.

Materials and methods. A search of journal databases including MEDLINE-Pubmed, Web of Science, Scopus, and Science Direct was used in this systematic review study. The inclusion criteria were papers that addressed cardiac troponin (cTn), physical activity, and myocardial infarction, and were published within the last five years. Using the databases Science Direct, Pubmed, and Web of Science, 83 recognized publications were found. For this systematic review, finally ten publications that fulfilled the requirements for inclusion were chosen and examined. This study evaluated standard operating procedures using the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA).

Results. This systematic review reports that physical exercise has been found to increase cardiac troponin (cTn) levels as a marker of myocardial infarction, but this increase is triggered by the body's physiological response during exercise and is not considered as a pathological response.

Conclusions. According to the findings of the study, physical exercise has been proven to elevate the risk of heart muscle damage by triggering an increase in cardiac troponin (cTn). However, this feature occurs in a physiological state and represents an exercise adaptation process. An analysis of the relevant articles reveals that this increase in cardiac troponin (cTn) has not been shown to have a negative influence on developing cardiovascular disease.

Keywords: cardiac troponin, physical exercise, myocardial infarction, healthy lifestyle.

Introduction

Regular physical exercise is strongly connected to better human life expectancy and has an impact on reducing morbidity, as well as mortality in cardiovascular disease (Ekelund et al., 2019). Regular exercise with moderate intensity is proven as a healthy lifestyle that can improve the health status of the human body (Bull et al., 2020). Consequently, according to global guidelines for physical activity, individuals should routinely exercise for 150–

300 minutes in a steady state or 75–150 minutes at a high intensity per week (Pelliccia et al., 2021). Acute exercise has long-term benefits, but if done incorrectly it can also have negative side effects, such as sudden cardiac death (Franklin et al., 2020). In addition, after prolonged exercise, endurance athletes may experience depression in left and right ventricular function; Nonetheless, after six hours of exercise, this impact is typical and frequently returns to baseline levels (Paul-Hus & Desrochers, 2019).

There are different viewpoints and debates regarding the pathological or physiological aspects of cTn release brought on by exercise. The increase in cTn after exercise is considered by some researchers to be a physiological reaction to exercise as it is frequent, occurs in the absence of clinical symptoms,

and often returns to normal within 24-72 hours after activity (S. L. Janssen et al., 2023). Increased cTn concentrations have been documented in research results throughout the last thirty years including among others the association with different types, duration, and intensity of exercise. These results have also been noted among a wide range of individuals, including age, gender, health conditions, and exercise type (Donaldson et al., 2019). The high levels of cTn induced by endurance training may compromise the cardiomyocyte sarcolemma. It might cause cTn particles to flow into the bloodstream. In addition, the amount of exertion induced by physical exercise that results in increased cTn concentrations has also been linked to the risk of developing occult obstructive coronary artery disease (Kleiven et al., 2020). However, this is still confusing and confusing among researchers.

Regular engagement in physical activity and exercise has been associated with a reduced prevalence of cardiovascular disease. It also has a positive impact on longevity (Aakre & Omland, 2019). Contrary to popular belief, a number of studies have shown that exercise, regardless of duration or level of intensity, is shown to immediately increase troponin concentrations (Aengevaeren et al., 2019). This exercise-induced increase in troponin concentration is considered benign as it occurs immediately after an activity session, will naturally return to normal, is observed in healthy individuals, and does not show any clinical signs. However, much remains to be learned about the processes and practical significance of troponin generated by exercise elevations which are still very complex (Aengevaeren et al., 2019). Therefore, this systematic review will attempt to discuss how physical exercise mechanisms increase cardiac troponin (cTn) levels. In addition, it will also provide recommendations whether this physical exercise with a review of cardiac troponin levels is a natural thing or will actually have a negative impact on health, researchers will discuss in this systematic review.

Materials and methods

Study Design

Searches via journals databases, like Science Direct, Web of Science, MEDLINE-Pubmed, and Scopus are used in this kind of systematic review study. Since it collects papers of scientific significance and influence, it is considered a leading platform worldwide.

Eligibility Criteria

The study's inclusion criteria were papers that discussed cardiac troponin (cTn), physical activity, and myocardial infarction, and were published in the previous five years. In addition, journals that did not meet scientific credibility standards or were not included in the Scopus and Web of Science indexes were excluded from this study.

Procedure

Article Full texts, abstracts, and titles were checked, confirmed, and entered into Mendeley software. A total of 83 publications were found during the first phase using the databases Web of Science, Pubmed, and Science Direct. 36 papers were then selected for screening in the second stage based on

whether the title and abstract met the criteria. In the third step, a total of 24 articles were asked to be processed further. We now filtered the articles according to their overall appropriateness. In the last phase of comprehensive investigation and observation, 10 papers that satisfied the inclusion criteria were chosen for analysis. For operational standards, this study adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) assessment.

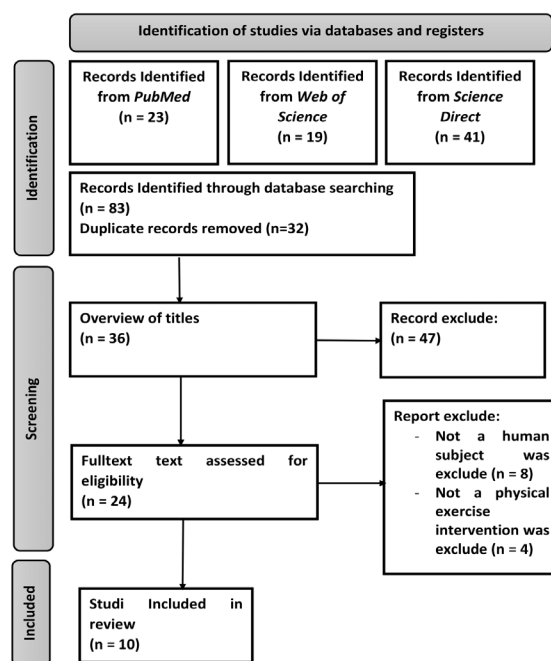


Fig. 1. PRISMA flowchart of the article selection process

Results

Description of Physical Exercise Increase Cardiac Troponin (cTn) Include in Review

The researchers found information regarding increased cardiac troponin (cTn) levels following exercise based on the papers examined. The rise in cardiac troponin levels is influenced by the length and intensity of exercise. The average intervention that has been given is physical exercise with moderate to high intensity. Both have a positive effect on increasing post-exercise cardiac troponin (cTn) levels as a marker of myocardial infarction.

Based on the 10 articles that have been analyzed (Tesema and George, 2021, Nguyen et al., 2023, Kastner et al., 2024, Orn et al., 2020, Bjorkavoll-Bergseth et al., 2024, Janssen et al., 2024, Paana et al., 2019, Cirer-Sastre et al., 2019, Birat et al., 2020, Cirer-Sastre et al., 2021) everything put into practice physical exercise interventions consisting of warm-up, core, and cool-down:

1. Warming up.
2. Moderate Intensity Physical Exercise.
3. High Intensity Physical Exercise.
4. Low Intensity Physical Exercise.
5. Stretching and Relaxation.

The participants of this study were humans consisting of athletes, untrained people, and trained people. This study did

Table 1. Summary of the design and intervention of the studies

Author	Design	Participants	Participants Age	Intervention	Outcome
Tesema & George, 2021	Randomized Controlled Trial	15	19.5 years old	1. Warm up for 5 minutes. 2. In the first week, maintain steady-state endurance running to 70% to 80% HRmax for 35 minutes per session. 3. And increase 2 minutes of exercise duration every week until 12 weeks of intervention.	1. Following exercise, there was a discernible rise in cTnI levels. Measuring Tools: Chemiluminescence Immunoassay. 2. cTnI levels are positively correlated with systolic blood pressure. Measuring Tools: Chemiluminescence Immunoassay. 3. cTnI levels showed a significant effect and positive relationship with resting heart rate. Measuring Tools: Chemiluminescence Immunoassay.
Nguyen et al., 2023	Randomized Controlled Trial	24	18 – 50 years old	High Intensity Training 1. Warm up for 10 minutes. 2. Running interval training on the treadmill every 5 minutes for 20 minutes until reaching VO ₂ Max. 3. Run by maintaining 80% - 95% of their HRMax for 30 minutes. Moderate Intensity Training. 1. Warm up for 10 minutes. 2. Running exercise on a treadmill maintaining 60% - 70% HRMax for 50 minutes. Low Intensity Training 1. Warm up for 10 minutes. 2. Running exercise on a treadmill maintaining 44% - 55% HRMax for 50 minutes.	1. There was an increase in troponin I and T levels in the group with high intensity training intervention both 2 hours, 4 hours and 6 hours after the intervention. Measuring instruments: ADVIA Centaur high sensitivity Troponin I immunoassay on ADVIA Centaur and STAT high sensitive Troponin I assay. Measuring Instruments: The Elecsys Troponin T hs assay on a Roche Cobas 8000 was used to quantify troponin T (cTnT). 2. There was an increase in troponin I and T 4 hours after the intervention in the moderate intensity training group. Measuring instruments: ADVIA Centaur high sensitivity Troponin I immunoassay on ADVIA Centaur and STAT high sensitive Troponin I assay. Measuring Instruments: The Elecsys Troponin T hs assay on a Roche Cobas 8000 was used to quantify troponin T (cTnT).
Kastner et al., 2024	Randomized Controlled Trial	36	22-24 years old	1. Running competition with a distance of 5 km for girls and 10 km for boys. 2. Ski sprint competition with a distance of 1.1 km performed 4 times by athletes.	1. There was an increase in troponin I in 3 male athletes. Measuring Tools : cobas Elecsys Troponin T hs STAT and High-Sensitivity Troponin I (TnIh) assay.
Orn et al, 2020	Randomized Controlled Trial	991	25-75 years old	1. Research participants completed a 91 km bicycle race in 2014. 2. Race duration was 3.4 - 4.3 hours.	1. After 3 hours of completing the race there was an increase in cTnI levels in 821 participants and 910 participants in the cTnI test that exceeded the 99th percentile limit. Measuring Tools : cTnI assay and cTnI assay. 2. After 24 hours of completing the race there was an increase in cTnI in 168 participants and an increase in cTnI in 264 participants that exceeded the 99th percentile limit. Measuring Tools : cTnI assay and cTnI assay.
Bjorkavoll-Bergseth et al., 2024	Randomized Controlled Trial	40	46-54 years old	Cardiopulmonary Exercise Test 1. Participants warm up for 10 minutes. 2. All participants exercise using an ergocycle that uses electronic brakes. 3. The VO ₂ max test was carried out for 5-10 minutes with participants doing the test on the ergocycle as much as possible until the VO ₂ max threshold. 4. Participants cool down. The Nort Sea Race 1. Participants cycled 91 km.	1. There was a significant increase in cTnI in all participants. Measuring Tools: hs-cTnI STAT assay at Architect SR2000i (Abbott Diagnostics, Abbot Park, IL, USA). 2. The highest increase in cTnI levels was found at 3 hours after undergoing both types of exercise interventions. Measuring Tools: hs-cTnI STAT assay at Architect SR2000i (Abbott Diagnostics, Abbot Park, IL, USA). 3. The increase in cTnI levels was higher after the race than during the cardiopulmonary exercise test. Measuring Tools: hs-cTnI STAT assay at Architect SR2000i (Abbott Diagnostics, Abbot Park, IL, USA).

Table 1 (continued)

Author	Design	Participants	Participants Age	Intervention	Outcome
S. L. J. E. Janssen et al., 2024	Randomized Controlled Trial	58	58-69 years old	Cycling Test 1. Participants begin with a 30-minute warm-up. 2. Exercise is performed at 70% HRmax. 3. Until fatigue, the physical demand was raised by 5% every three minutes. 4. Cooling down for 3 minutes.	1. There was an increase in cTnT and cTnI levels after physical exercise intervention. 2. Measuring Tools : the Cobas 6000 analyzer (Troponin T Gen 5 STAT, Roche Diagnostics, Mannheim, Germany) and the ALINITY ci-series analyzer (Alinity i STAT High Sensitive Troponin-I Reagent Kit, Abbott Diagnostics, Abbott Park, IL). 3. There was an increase in cTnT and cTnI levels at 180 minutes post exercise. Measuring instruments: ALINITY ci-series analyzer (Alinity i STAT High Sensitive Troponin-I Reagent Kit, Abbott Diagnostics, Abbott Park, IL), and Cobas 6000 analyzer (Troponin T Gen 5 STAT, Roche Diagnostics, Mannheim, Germany).
Paana et al., 2019	Randomized Controlled Trial	43	Age: 12 (less than 35), 31 (more than 44) years old	1. MaraCat Study participants were first recruited to take part in the 2018 Paavo Nurmi Marathon in Turku.	1. Post-marathon cTnT concentrations increased below the reference standard in 38 participants. Measuring Tools : Commercial high-sensitive assay (Roche Diagnostics GmbH, Mannheim, Germany). 2. None of the participants reported post-marathon cardiac symptoms. Measuring Tools : Commercial high-sensitive assay (Roche Diagnostics GmbH, Mannheim, Germany). 3. Age significantly correlates with cTnT concentration after marathon. Measuring Tools : Commercial high-sensitive assay (Roche Diagnostics GmbH, Mannheim, Germany).
Cirer-Sastre, Legaz-Arrese, Corbi, López-Laval, et al., 2019	Randomized Controlled Trial	20	Age < > 11.9 years old	1. Research participants warm up for 15 minutes. 2. Physical exercise small soccer 5x5 for 16 minutes with interval rest 3 minutes every 4 minutes exercise. 3. Then cool down.	1. There was an increase in hs-cTnT levels peaking at 3 hours after exercise in all participants. Measuring Tools : Troponin T hs STAT immunoassay using Roche Diagnostics' Cobas E 601 analyzer (Penzberg, Germany).

Table 1 (continued)

Author	Design	Participants	Participants Age	Intervention	Outcome
Birat et al., 2020	Randomized Controlled Trial	12	14 – 15 years old	Session 1 VO₂Max Test - The first session subjects took anthropometric measurements and body mass index measurements and continued with the VO₂max test. - The test begins with a warm-up using an ergocycle for 4 minutes. - Participants perform the test using an ergocycle with 95% HRMax. Session 2 - A competitive 42.7-kilometer adventure race for volunteers was part of the second session. - A variety of endurance-based sports were included in the race: Trail jogging (4.1 km), mountain biking (27.0 km), kayaking (4.4 km), and inline skating (4.2 km). The previous evening, a 5.5 km long run before the marathon. Each competitor traveled 48.2 kilometers in total ("1-day race"). Session 3 - During the third session, the volunteers competed in a 59.0 km race over two days. - By participating in a series of mixed-modality endurance activities spread over two days (32.0 km on Day 1 and 27.0 km on Day 2), comprising 14.0 km of trail running, 27.0 km of mountain biking. - a 7.0 km trail run takes place the night before the marathon. Each competitor has traveled 66.0 kilometers in total ("2-day race").	There was an increase in cTnI levels in participants during the first race session immediately after the race. The i-STAT cTnI portable analyzer, manufactured by Abbott Point of Care, Inc. in Princeton, NJ, is the measuring tool used.
Cirer-Sastre et al., 2021	Randomized Controlled Trial	32	11 – 52 years old	Swimming - Before the intervention, participants warmed up by swimming independently for 5 minutes. - Participants performed long-distance swimming for 45 minutes. - Participants cool down.	- There was an increase in cTnT immediately after the swimming intervention. Measuring Tools : Troponin T hs STAT immunoassay in a Cobas E 601 analyzer (Roche Diagnostics, Penzberg, Germany) with a range of 3–10,000 ng/L. - There was the highest increase in cTnT 3 hours after the swimming intervention. Troponin T hs STAT immunoassay in a Cobas E 601 analyzer (Roche Diagnostics, Penzberg, Germany) with a range of 3–10,000 ng/L is the measuring tool used.

not include animal participants since the criteria for inclusion were not met (Tesema and George, 2021, Nguyen et al., 2023, Kastner et al., 2024, Orn et al., 2020, Bjorkavoll-Bergseth et al., 2024, Janssen et al., 2024, Paana et al., 2019, Cirer-Sastre et al., 2019, Birat et al., 2020, Cirer-Sastre et al., 2021).

Report results from research Cirer-Sastre et al. (2019) proved that the highest increase in cardiac troponin (cTn) occurred at 3 hours after the administration of physical exercise intervention. Other research from Cirer-Sastre et al. (2021) also proved the same thing, notably, that three hours following the physical activity intervention, the rise in cardiac troponin (cTn) levels peaked. Another report from Bjorkavoll-Bergseth et al. (2024) also said the same thing that 3 hours is the peak time of cardiac troponin increase after physical exercise. Of course, differences in the concentration of cardiac troponin levels are also caused by many factors including the duration of exercise, type of exercise, and research samples, as well as blood sampling methods.

From the overall review results that have been analyzed also prove that There is no correlation between the rise in cardiac troponin brought on by physical exercise treatments and a higher risk of cardiovascular disease. Based on existing data, it proves that cardiac troponin levels will decrease by themselves after peaking in healthy people (Tesema and George, 2021, Nguyen et al., 2023, Kastner et al., 2024, Orn et al., 2020, Bjorkavoll-Bergseth et al., 2024, Janssen et al., 2024, Paana et al., 2019, Cirer-Sastre et al., 2019, Birat et al., 2020, Cirer-Sastre et al., 2021). So the increase in cardiac troponin during physical exercise is not a trigger for cardiovascular disease. However, it is still a debate among researchers whether the rise in heart troponin levels with physical activity is a physiological factor or even a pathological factor is still confusing and needs further exploration.

Intensity and Type of Physical Exercise Influence Differences in Cardiac Troponin (cTn) Concentrations

The type of exercise intervention affects the concentration of cardiac troponin levels. Based on the data that has been taken from the study Nguyen et al., 2023 that high-intensity exercise was shown to increase cardiac troponin levels higher than moderate-intensity exercise 4 hours post-intervention. And low-intensity exercise has lower cardiac troponin levels than high-intensity exercise and moderate-intensity exercise (Nguyen et al., 2023). Elevated cardiac troponin during exercise has a strong effect on increasing cardiovascular risk in people with cardiovascular disease, but not in people without cardiovascular disease (Bjorkavoll-Bergseth et al., 2024).

Research results from Cirer-Sastre et al. (2021) with subjects who were given a swimming intervention with a maximum of 45 minutes proved that cardiac troponin increased shortly after the intervention and peaked at 3 hours post exercise. The value of cardiac troponin (cTn) concentration seems to be lower in young age than old age, and this can be explained that age affects the prevalence of an increase in cardiovascular disease patients (Cirer-Sastre et al., 2019). Interestingly although the increase in cTn peaked 3 hours after the physical exercise intervention, however Cirer-Sastre et al. (2021) in his study found that there was an increase shortly after the highest exercise cTn levels in adults.

It may be that cTn elevations appear earlier compared to teenagers, in adults. Additionally, it is expanding

evidence that exercise-induced cTn elevations in apparently healthy athletes may respond physiologically rather than pathologically (Baker et al., 2019). Cardiac troponin is indeed one of the biomarkers of myocardial infarction. However, especially during exercise, cTn levels increase immediately after exercise. This is highly debatable as cTn is essentially a marker of myocardial infarction.

Discussion

This study aims to examine the relationship in between exercises that can increase cardiac troponin (cTn) levels as one of the biomarkers of myocardial infarction. From the journal database search, 10 relevant articles were found according to the inclusion criteria. Due to the limited research related to cardiac troponin, the author is more focused and concentrated on this topic. Report results from Nguyen et al. (2023) proved that high-intensity exercise had higher cardiac troponin levels than low- and moderate-intensity exercise. We all know that regular exercise is a therapy that is very beneficial for the body and has a protective effect in reducing the risk of cardiovascular disease. However, other studies claim that following cardiac troponin (cTn) levels rise with physical exercise, which causes heart injury (Celeski et al., 2024).

Troponin is a complex protein that is attached to tropomyosin found in all skeletal and cardiac muscle cells (Aakre & Omland, 2019). The increase in cTn levels after physical exercise is highly variable based on how long and how hard the workout is (Aengevaeren, Baggish, Chung, George, Kleiven, Mingels, Ørn, Shave, Thompson, et al., 2021). Several investigations have been conducted to explore what factors influence and contribute to the high release of specific biomarkers of myocardial infarction markers. The high levels of cTn were found to be influenced by several factors including age, trained person, blood pressure, surrounding conditions, level of exertion, and length of exercise (Aengevaeren, Baggish, Chung, George, Kleiven, Mingels, Ørn, Shave, Thompson, et al., 2021). During physical exercise, the heart's oxygen demand in the body increases significantly (Heusch, 2019). The sole biomarker recommended for the diagnosis of myocardial infarction is cardiac troponin (cTn) in clinical practice (Taggart & Chapman, 2024).

Exercise training has been shown to have a beneficial impact on the cardiovascular system. The overall physiological changes that result from physical exercise induce a rise in cardiac output, heart rate, and stroke volume in response to exercise (Chen et al., 2022). Moreover, physical activity of the right intensity and duration can provide benefits in improving enhancing respiratory and cardiovascular fitness and lowering the risk of cardiovascular disease and other causes of death (Ezzatvar et al., 2021). WHO recommendations in 2020 that physical exercise at a moderate to high intensity is recommended to be done routinely and regularly (Bull et al., 2020). Regular physical exercise also has a beneficial effect on the occurrence of cardiac muscle hypertrophy, a condition in which the mass of the heart muscle increases and results in increased heart protection (Chen et al., 2022). Exercise-induced hypertrophy physiologically has different features and characteristics than pathologically induced hypertrophy (Li et al., 2022).

Researchers disagree on the rise in cardiac troponin after exercise. It is known that an increase in cTn during exercise is normal because it is a physiological response and

not a pathological response (Aengevaeren, Baggish, Chung, George, Kleiven, Mingels, Ørn, Shave, & Thompson, 2021). It should be noted that physical exercise is proven to improve the health status of the human body (Hussey & Gupta, 2023). During exercise, the body will activate the sympathetic nervous system (Moscatelli et al., 2022) and releases the hormone catecholamin (Er et al., 2024). The function of the heart is significantly improved during physical exercise (Lavie et al., 2023). The working mechanism of the heart muscle is also very extra to fulfill the supply of oxygen to all capillaries (Paluch et al., 2024). From the results of the study mentioned that the increase in cTn levels during physical exercise has an impact on the occurrence of cardiac muscle hypertrophy and exercise can be concluded to induce a temporary increase in troponin caused by a temporary increase in cardiomyocyte membrane permeability (Aengevaeren et al., 2019).

It is known that an increase in cTn is synonymous with an increased risk of cardiovascular disease. However, this does not apply and does not occur in people who have done physical exercise. Because the results of several studies did not mention any disorders related to increased cardiovascular system disease (Cirer-Sastre et al., 2019; Birat et al., 2020; Janssen et al., 2024). Post-physical exercise there were also no problems with the heart despite the increase in cTn (Nguyen et al., 2023). Further analysis and research is needed regarding the duration or other factors that influence the increase in cTn after physical exercise. cTn levels rise and are shown to also decrease and return to normal limits some time after the increase in cTn triggered by physical exercise (Tesema & George, 2021). So it can be said that the increase in cTn levels is normal because it is a physiological response to exercise and not pathological. Now the impact of the increase in cTn during exercise can be further analyzed and researched in order to provide understanding to academics and practitioners about its effect on other factors.

Strenght and Limitations

One of the advantages of this systematic review is that it only examines controlled trials conducted at random, which are as the most trustworthy type of scientific data because there is no possibility of unclear causal relationships. The provision of regular physical exercise and its impact on cTn improvement is very relevant with a detailed discussion of its role so as to recommend physical exercise as a preventive measure and can improve the workings of the cardiovascular system. The restriction we ran across is that there are scarcely any recent studies that address this issue, which show that the increase in cTn levels after physical exercise has a beneficial impact, has not received much attention, even though the improvement of human quality of life can be improved depending on how we can regularly perform physical exercises that can lower the risk of degenerative diseases like heart disease which is a serious problem globally.

Conclusions

Considering the related articles that we discovered, it can be concluded that regular physical training can increase cTn levels after exercise. However, this is a physiological adaptation response to exercise that does not increase the risk of myocardial infarction.

Conflicts of Interest

The authors declare no conflict of interest.

References

- Ekelund, U., Tarp, J., Steene-Johannessen, J., Hansen, B. H., Jefferis, B., Fagerland, M. W., Whincup, P., Diaz, K. M., Hooker, S. P., Chernofsky, A., Larson, M. G., Spartano, N., Vasan, R. S., Dohrn, I. M., Hagströmer, M., Edwardson, C., Yates, T., Shiroma, E., Anderssen, S. A., & Lee, I. M. (2019). Dose-response associations between accelerometry measured physical activity and sedentary time and all cause mortality: Systematic review and harmonised meta-analysis. *The BMJ*, 366, 1-10. <https://doi.org/10.1136/bmj.l4570>
- Bull, F. C., Al-Ansari, S. S., Biddle, S., Borodulin, K., Buman, M. P., Cardon, G., Carty, C., Chaput, J. P., Chastin, S., Chou, R., Dempsey, P. C., Dipietro, L., Ekelund, U., Firth, J., Friedenreich, C. M., Garcia, L., Gichu, M., Jago, R., Katzmarzyk, P. T., ... Willumsen, J. F. (2020). World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *British Journal of Sports Medicine*, 54(24), 1451-1462. <https://doi.org/10.1136/bjsports-2020-102955>
- Pelliccia, A., Sharma, S., Gati, S., Bäck, M., Björjesson, M., Caselli, S., Collet, J.-P., Corrado, D., Drezner, J. A., Halle, M., Hansen, D., Heidbuchel, H., Myers, J., Niebauer, J., Papadakis, M., Piepoli, M. F., Prescott, E., Roos-Hesselink, J. W., Graham Stuart, A., ... Rakhit, D. (2021). 2020 ESC Guidelines on sports cardiology and exercise in patients with cardiovascular disease. *European Heart Journal*, 42(1), 17-96. <https://doi.org/10.1093/eurheartj/ehaa605>
- Franklin, B. A., Thompson, P. D., Al-Zaiti, S. S., Albert, C. M., Hivert, M. F., Levine, B. D., Lobelo, F., Madan, K., Sharrief, A. Z., & Eijsvogels, T. M. H. (2020). Exercise-Related Acute Cardiovascular Events and Potential Deleterious Adaptations Following Long-Term Exercise Training: Placing the Risks into Perspective-An Update: A Scientific Statement from the American Heart Association. *Circulation*, 141(13). <https://doi.org/10.1161/CIR.0000000000000749>
- Paul-Hus, A., & Desrochers, N. (2019). Acknowledgements are not just thank you notes: A qualitative analysis of acknowledgements content in scientific articles and reviews published in 2015. *PLoS ONE*, 14(12), 1-13. <https://doi.org/10.1371/journal.pone.0226727>
- Janssen, S. L., Berge, K., Luiken, T., Aengevaeren, V. L., & Eijsvogels, T. M. (2023). Cardiac troponin release in athletes: what do we know and where should we go? *Current Opinion in Physiology*, 31(January), 100629. <https://doi.org/10.1016/j.cophys.2022.100629>
- Donaldson, J. A., Wiles, J. D., Coleman, D. A., Papadakis, M., Sharma, R., & O'Driscoll, J. M. (2019). Left Ventricular Function and Cardiac Biomarker Release—The Influence of Exercise Intensity, Duration and Mode: A Systematic Review and Meta-Analysis. *Sports Medicine*, 49(8), 1275-1289. <https://doi.org/10.1007/s40279-019-01142-5>
- Kleiven, Ø., Omland, T., Skadberg, Ø., Melberg, T. H., Bjørkavoll-Bergseth, M. F., Auestad, B., Bergseth, R., Greve, O. J., Aakre, K. M., & Ørn, S. (2020). Occult obstructive coronary artery disease is associated with prolonged cardiac troponin elevation following strenuous exercise. *European Journal of Preventive Cardiology*,

- 27(11), 1212-1221.
<https://doi.org/10.1177/2047487319852808>
- Aakre, K. M., & Omland, T. (2019). Physical activity, exercise and cardiac troponins: Clinical implications. *Progress in Cardiovascular Diseases*, 62(2), 108-115.
<https://doi.org/10.1016/j.pcad.2019.02.005>
- Aengevaeren, V. L., Hopman, M. T. E., Thompson, P. D., Bakker, E. A., George, K. P., Thijssen, D. H. J., & Eijssvogels, T. M. H. (2019). Exercise-Induced Cardiac Troponin I Increase and Incident Mortality and Cardiovascular Events. *Circulation*, 140(10), 804-814.
<https://doi.org/10.1161/CIRCULATIONAHA.119.041627>
- Tesema, G., & George, M. (2021). Associations between cardiac troponin i and cardiovascular parameters after 12-week endurance training in young moderately trained amateur athletes. *BMJ Open Sport and Exercise Medicine*, 7(1), 14-16. <https://doi.org/10.1136/bmjsem-2021-001065>
- Nguyen, D. K., Ellingsen, Ø., Grenne, B., Fremo, T., Hov, G. G., Røsbjorgen, R., & Mikkelsen, G. (2023). Treadmill running intensity and post-exercise increase in plasma cardiac troponin I and T—A pilot study in healthy volunteers. *Scandinavian Journal of Medicine and Science in Sports*, 33(12), 2499-2508.
<https://doi.org/10.1111/sms.14484>
- Kastner, T., Froberg, F., Hesse, J., & Wolfarth, B. (2024). *Exercise-Induced Troponin Elevation in High-Performance Cross-Country Skiers*. <https://doi.org/10.3390/jcm13082335>
- Orn, S., Melberg, T., Omland, T., Skadberg, O., Bjorkavoll-Bergseth, M., Erevik, C., Hansen, M., Auestad, B., Bergseth, R., Aakre, K., & Kleiven, O. (2020). Is cardiac troponin elevation following strenuous exercise clinically relevant in healthy subjects? *European Heart Journal*, 41(Supplement_2), 3121.
<https://doi.org/10.1093/ehjci/ehaa946.3121>
- Bjorkavoll-Bergseth, M., Erevik, C., Kleiven, Ø., Wiktorski, T., Auestad, B., Skadberg, Ø., Aakre, K. M., Eijssvogels, T. M. H., & Ørn, S. (2024). The relationship between workload and exercise-induced cardiac troponin elevations is influenced by non-obstructive coronary atherosclerosis. *Scandinavian Journal of Medicine and Science in Sports*, 34(5), 1-13. <https://doi.org/10.1111/sms.14667>
- Janssen, S. L. J. E., De Vries, F., Mingels, A. M. A., Kleinnibbelink, G., Hopman, M. T. E., Mosterd, A., Velthuis, B. K., Aengevaeren, V. L., & Eijssvogels, T. M. H. (2024). Exercise-induced cardiac troponin release in athletes with versus without coronary atherosclerosis. *American Journal of Physiology - Heart and Circulatory Physiology*, 326(4), H1045-H1052.
<https://doi.org/10.1152/ajpheart.00021.2024>
- Paana, T., Jaakkola, S., Bamberg, K., Saraste, A., Tuunainen, E., Wittfooth, S., Kallio, P., Heinonen, O. J., Knuuti, J., Pettersson, K., & Airaksinen, K. E. J. (2019). Cardiac troponin elevations in marathon runners. Role of coronary atherosclerosis and skeletal muscle injury. The MaraCat Study. *International Journal of Cardiology*, 295, 25-28. <https://doi.org/10.1016/j.ijcard.2019.08.019>
- Cirer-Sastre, R., Corbi, F., López-Laval, I., Carranza-García, L. E., & Reverter-Masià, J. (2021). Exercise-induced release of cardiac troponins in adolescent vs. Adult swimmers. *International Journal of Environmental Research and Public Health*, 18(3), 1-6.
<https://doi.org/10.3390/ijerph18031285>
- Cirer-Sastre, R., Legaz-Arrese, A., Corbi, F., George, K., Nie, J., Carranza-García, L. E., & Reverter-Masià, J. (2019). Cardiac biomarker release after exercise in healthy children and adolescents: A systematic review and meta-analysis. *Pediatric Exercise Science*, 31(1), 18-36.
<https://doi.org/10.1123/pes.2018-0058>
- Cirer-Sastre, R., Legaz-Arrese, A., Corbi, F., López-Laval, I., Puente-Lanzarote, J., Hernández-González, V., & Reverter-Masià, J. (2019). Effect of training load on post-exercise cardiac troponin T elevations in young soccer players. *International Journal of Environmental Research and Public Health*, 16(23).
<https://doi.org/10.3390/ijerph16234853>
- Birat, A., Bourdier, P., Dodu, A., Grosseuvre, C., Blazeovich, A. J., Amiot, V., Dupont, A. C., Nottin, S., & Ratel, S. (2020). Effect of Long-Duration Adventure Races on Cardiac Damage Biomarker Release and Muscular Function in Young Athletes. *Frontiers in Physiology*, 11(February), 1-9.
<https://doi.org/10.3389/fphys.2020.00010>
- Baker, P., Leckie, T., Harrington, D., & Richardson, A. (2019). Exercise-induced cardiac troponin elevation: An update on the evidence, mechanism and implications. *IJC Heart and Vasculture*, 22, 181-186.
<https://doi.org/10.1016/j.ijcha.2019.03.001>
- Celeski, M., Segreti, A., Piscione, M., Monticelli, L. M., Di Gioia, G., Fossati, C., Ussia, G. P., Pigozzi, F., & Grigioni, F. (2024). The current paradigm of cardiac troponin increase among athletes. *Monaldi Archives for Chest Disease*. <https://doi.org/10.4081/monaldi.2024.2878>
- Aengevaeren, V. L., Baggish, A. L., Chung, E. H., George, K., Kleiven, Ø., Mingels, A. M. A., Ørn, S., Shave, R. E., Thompson, P. D., & Eijssvogels, T. M. H. (2021). Exercise-Induced Cardiac Troponin Elevations: From Underlying Mechanisms to Clinical Relevance. *Circulation*, 144(24), 1955-1972.
<https://doi.org/10.1161/CIRCULATIONAHA.121.056208>
- Heusch, G. (2019). Myocardial ischemia: Lack of coronary blood flow, myocardial oxygen supply-demand imbalance, or what? *American Journal of Physiology - Heart and Circulatory Physiology*, 316(6), H1439-H1446.
<https://doi.org/10.1152/ajpheart.00139.2019>
- Taggart, C., & Chapman, A. R. (2024). Cardiac troponin and the diagnosis of type 2 myocardial infarction and acute non-ischaemic myocardial injury. *Journal of Laboratory and Precision Medicine*, 9.
<https://doi.org/10.21037/jlpm-23-40>
- Chen, H., Chen, C., Spanos, M., Li, G., Lu, R., Bei, Y., & Xiao, J. (2022). Exercise training maintains cardiovascular health: signaling pathways involved and potential therapeutics. *Signal Transduction and Targeted Therapy*, 7(1). <https://doi.org/10.1038/s41392-022-01153-1>
- Ezzatvar, Y., Izquierdo, M., Núñez, J., Calatayud, J., Ramírez-Vélez, R., & García-Hermoso, A. (2021). Cardiorespiratory fitness measured with cardiopulmonary exercise testing and mortality in patients with cardiovascular disease: A systematic review and meta-analysis. *Journal of Sport and Health Science*, 10(6), 609-619. <https://doi.org/10.1016/j.jshs.2021.06.004>
- Li, H., Trager, L. E., Liu, X., Hastings, M. H., Xiao, C., Guerra, J., To, S., Li, G., Yeri, A., Rodosthenous, R., Silverman, M. G., Das, S., Ambardekar, A. V., Bristow, M. R., González-Rosa, J. M., & Rosenzweig, A. (2022). LncExACT1 and DCHS2 Regulate Physiological and Pathological Cardiac Growth. *Circulation*, 145(16), 1218-1233.
<https://doi.org/10.1161/CIRCULATIONAHA.121.056850>
- Hussey, C., & Gupta, A. (2023). *Physical activity and its impact on the health of young people*. December.

Moscatelli, F., Sessa, F., Valenzano, A., Polito, R., Eronia, S., & Monda, V. (2022). The Influence of Physical Exercise, Stress and Body Composition on Autonomic Nervous System: A Narrative Review. *Sport Mont*, 20(2), 131-134. <https://doi.org/10.26773/smj.220620>

Er, F., Yilmaz, C., Polat, M., Kuzucu, Ö. E., & Suveren, C. (2024). Effect of Physical Exercise on Catecholamine Levels in Individuals over 65 Years of Age. *International Journal of Human Movement and Sports Sciences*, 12(3), 463-470. <https://doi.org/10.13189/saj.2024.120302>

Фізичні вправи підвищують рівень серцевого тропоніну (сТн) як маркера інфаркту міокарда: Систематичний огляд

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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., 34 джерела.

Мета дослідження. Метою цього дослідження було проаналізувати показник впливу фізичних вправ на підвищення рівня серцевого тропоніну (сТн) як маркера інфаркту міокарда з фізіологічної точки зору.

Матеріали та методи. У цьому систематичному оглядовому дослідженні використовували пошук видань, що індексуються у наукометричних базах даних, включаючи MEDLINE-Pubmed, Web of Science, Scopus і Science Direct. Критеріями включення були роботи, які стосувалися дослідження серцевого тропоніну (сТн), фізичної активності та інфаркту міокарда, а також були опубліковані впродовж останніх п'яти років. За допомогою наукометричних баз даних Science Direct, Pubmed та Web of Science було знайдено 83 авторитетні публікації. З метою проведення систематичного огляду було відібрано та досліджено десять публікацій, які відповідали критеріям включення. У цьому дослідженні проведена оцінка стандартних методів роботи із використанням «Переважних елементів звітності для систематичних оглядів і мета-аналізів» (PRISMA).

Результати. У цьому систематичному огляді зазначається, що фізичні вправи підвищують рівень серцевого тропоніну (сТн) як маркера інфаркту міокарда, однак це підвищення спричинено фізіологічною реакцією організму під час виконання фізичних вправ і не розглядається як патологічна реакція.

Висновки. Згідно з результатами дослідження, доведено, що фізичні вправи збільшують ризик пошкодження серцевого м'яза внаслідок підвищення рівня серцевого тропоніну (сТн). Однак цей ефект спостерігається у фізіологічному стані і представляє собою процес адаптації до фізичних навантажень. Аналіз відповідних наукових статей показує, що таке підвищення серцевого тропоніну (сТн) не має негативного впливу на розвиток серцево-судинних захворювань.

Ключові слова: серцевий тропонін, фізичні вправи, інфаркт міокарда, здоровий спосіб життя.

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