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[Teorìâ ta Metodika Fìzičnogo Vihovannâ]

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Original scientific article

The Effects of an 8-Week Strength Training Toward the Specific Preparation Phase on Male Volleyball Athletes' Performance

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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. Training programs are part of training management that need to be properly and correctly prepared and implemented.

Study purpose. The aim of the study was to evaluate the effects of an 8-week program of resistance training, carried out at a specific preparation phase, on the performance of male junior volleyball athletes.

Materials and methods. This study was conducted as experimental research, with a sample of 24 male volleyball athletes ([mean ± SD] age: 17.96 ± 1.23 years; body weight: 75.56 ± 7.80 kg; height: 180.46 ± 7.14 cm; body fat: 17.62 ± 3.36%) who were randomly divided into experimental group (EG): n = 12 and control group (CG): n = 12. The training program lasted for eight weeks and took place at a specific preparation phase.

Results. There was a significant increase in the indicators handgrip dynamometer left ($p<0.014$), handgrip dynamometer right ($p<0.001$), vertical jump ($p<0.001$), sit-and-reach test ($p<0.000$), leg dynamometer ($p<0.000$), and back dynamometer ($p<0.001$) in the experimental group after being given strength training treatment for eight weeks.

Conclusions. When strength training is included in volleyball training, it can increase the performance in power, strength, and flexibility, especially when carried out at a specific preparation phase. Incorporating targeted stimuli, such as strength training, into training sessions appears to be a secure method of training for this age group and may help to contribute to continuous and gradual improvements in neuromuscular adaptation.

Keywords: volleyball, performance, strength training.

Introduction

The biomotor component significantly influences performance during training and competition. In volleyball, athletes' success hinges on their biomotor components, encompassing strength, explosive power, speed, flexibility, and agility (Lehnert et al., 2017). Athletes are tasked with enhancing their performance through the development of these biomotor components (Salafi et al., 2023). According to Blumenstein & Orbach (2020), training represents a systematic process aimed at optimizing athletes' performance. A literature review suggests that achieving Olympic champion or international athlete status in a specific sport necessitates approximately ten years or 10,000 hours of effective and structured training (Haugen, Seiler, Sandbakk, & Tønnessen, 2019). The attainment of remarkable athletic feats is inseparable from the coach's guidance, a well-designed training program, and the harmonious integration of various factors.

An effective training regimen should have well-defined objectives, encompassing the enhancement of physical, technical, and psychological skills (Blumenstein & Orbach, 2020). Schroepf & Lames (2018) emphasize that the aim of training is to elevate performance, enhance athletes' competence, and refine planning strategies and self-control (Peng, Othman, Yuan, & Liang, 2022; Wee & Dillon, 2022). Consequently, effective training entails clear goals, objectives, and systematic implementation. To ensure an ideal training process, exercises should adhere to the principles of

periodization. Periodization is crucial for optimizing athlete performance, involving the segmentation of training phases into focused segments. It has emerged as a vital planning paradigm for advancing athlete performance, shaping beliefs and coaching traditions through the application of comprehensive scientific knowledge and significant advancements in the fields of nutrition, technical, and physical training (Kiely, 2018; Otte, Millar, & Klatt, 2019).

Bompa and Buzzichelli (2019:93) delineate that training periodization comprises two pivotal components: (1) annual training periodization planning and (2) dominant biomotor periodization. The annual training periodization encompasses three phases: (1) the preparatory phase, (2) the competition phase, and (3) the transition phase. Moreover, the preparatory phase is further divided into the general preparation phase and the specific preparation phase. During the specific preparation phase, training is concentrated on cultivating specialized physical and dominant biomotor components (Bompa & Buzzichelli, 2019).

The specific preparation period entails training that targets specific physical and technical abilities within a particular sport, with the aim of enhancing performance. As per Blumenstein & Orbach (2020), the objective of this phase is to optimize the athlete's physical development in alignment with the physiological and physical demands of the activity. This phase is characterized by substantial training loads, high training intensity, and the refinement of targeted techniques (Bompa & Buzzichelli, 2019). In team sports, the training endeavors to cultivate techniques, tactics, and physical attributes based on the sport's characteristics in readiness for the pre-competition phase. When it comes to developing physical abilities, it is acknowledged that resistance training can contribute to improved muscle adaptations, encompassing endurance, hypertrophy, strength, and muscle power. However, the extent of the impact of resistance training on muscle adaptation varies significantly based on the training modality employed, with muscle adaptation being contingent on various factors such as training intensity, volume (reps, sets), rest periods, movement rhythm, and more.

The resistance training program is a crucial component of training management that must be carefully prepared and executed. A key aspect of developing a resistance training program involves determining the training dosage and adjusting the training periodization to enhance the athlete's performance and ensure it aligns with the target. At the time this research was conducted, there was a scarcity of reference sources in the field of volleyball resistance training. The existing research on volleyball resistance training predominantly focused on elite athletes or those with extensive training, resulting in a lack of literature addressing resistance training for junior athletes. Additionally, there was limited information available on the influence of resistance training across different training phases. Therefore, this study aimed to investigate whether incorporating strength training alongside technical and tactical training exercises during the specific preparation period can impact the physical performance of junior volleyball athletes. The research sought to evaluate the effects of an eight-week strength training program, conducted within a specific preparation phase, on the performance of junior male volleyball players.

Materials and methods

Participants

The sample of this study involved 24 male volleyball athletes, with the following characteristics: mean age of 17.96±1.23 years, weight of 75.56±7.80 kg, height of 180.46±7.14 cm, and body fat percentage of 17.62±3.36%. The participants were randomly divided into two groups: the experimental group (EG) consisting of 12 athletes, and the control group (CG) also consisting of 12 athletes, with an equal number of athletes per position in each group. These junior athletes were in preparation for the Regional Sports Week and had completed the general preparatory phase of training.

Experimental design

This research was designed to answer two questions: (1) Is there an effect of Strength Training (ST) on the performance of male volleyball athletes in the specific preparation phase? (2) How big is the effect (ES) before and after giving the intervention to each group? To investigate these questions, the EG was given strength training interventions, technical/tactical training, and friendly matches. Meanwhile, the CG received technical/tactical training interventions and friendly matches.

During an intensive eight-week preparatory period, the study focused on a mesocycle plan that included strength training for the EG and tactical and technical training for volleyball matches. The distribution of training sessions over the eight weeks is illustrated in Table 1. The technical/tactical training model encompassed various aspects such as serving, passing, smashing, blocking, defending, and attacking. Meanwhile, the strength training model, which comprised five phases, involved gym-based exercises utilizing body weight and equipment (free-weights and machines). These phases included static and dynamic stabilization, anatomical adaptation, maximum strength, and power. To regulate exercise intensity, the researchers employed heart rate control and 1 Repetition Maximum (RM) testing. Throughout the study, the training program's intensity ranged from 40% to 80% of 1 RM.

Testing procedure

The testing session was conducted at the same place and time (±2 hours) for each participant in the same condition, without injury, and not after a match or high-intensity training. Body composition was also measured during the testing. Throughout the exam, participants received a lot of verbal encouragement to put forth their best effort. The participants were instructed to stretch for around fifteen minutes before the exam.

Vertical Jump (VJ)

The Vertical Jump test is utilized to assess athletes' jumping performance and indirectly measure lower body strength in the vertical plane (Banda, Beitzel, Kammerer, Salazar, & Lockie, 2019). The necessary tools for conducting this test include a board attached to the wall at a height ranging from 150 to 350 cm, powdered chalk or flour, and a blackboard eraser. Initially, the fingertips are coated with lime powder or

Table 1. Training sessions distribution in the intervention period

Days	Period	Week 1-2	Week 3-4	Week 5-6	Week 7-8
Monday	Morning	ST (EG)/ TTT (CG)	TTT	ST+TTT (EG)/ TTT (CG)	ST+TTT (EG)/ TTT (CG)
	Evening	TTT	TTT	OFF	TTT
Tuesday	Morning	OFF	ST (EG)/TTT(CG)	OFF	OFF
	Evening	TTT	OFF	TTT	TTT
Wednesday	Morning	OFF	TTT	OFF	ST (EG)/ TTT (CG)
	Evening	OFF	TTT	ST (EG)/TTT(CG)	OFF
Thursday	Morning	ST (EG)/ TTT (CG)	OFF	OFF	OFF
	Evening	OFF	OFF	FM	FM
Friday	Morning	TTT	ST (EG)/TTT(CG)	OFF	OFF
	Evening	OFF	OFF	OFF	OFF
Saturday	Morning	TTT	TTT	TTT	TTT
	Evening	OFF	FM	FM	FM
Sunday	Morning	OFF	OFF	OFF	OFF
	Evening	OFF	OFF	OFF	OFF
N Sessions		6	8	6	7

*Legend: ST: Strength Training; TTT: Tactic/Teknik Training; FM: Friendly Matches; CG: Control Group; EG: Experimental Group.

magnesium carbonate, after which the participant stands upright near the wall with feet together and scales the board to the left or right. Subsequently, the palm of the hand near the wall is placed on a calibrated board to create a reach mark, followed by raising the hand straight up. The exercise begins with participants assuming a bowed knee position, while the dominant hand or arm is raised vertically, and the other arm is held alongside the body, with any swinging motion to aid in leaping momentum strictly prohibited. The players then leap as high as possible, tapping their fingers against the board to leave a mark. The assessment involves calculating the difference between the jumping achievement and standing achievement. Each participant is given two opportunities to perform this test, and the coach records the best results.

Leg and Back Dynamometer

The leg dynamometer (LD) is an equipment used to assess the static strength of leg muscles. In the meanwhile, the back dynamometer (BD) is designed to assess the static strength of the back muscles. The method for making decisions on this test is by recording the highest weight of the three lifting occasions in kg, with an accuracy level of 0.5 kg.

Handgrip dynamometer

The handgrip dynamometer is utilized to assess hand squeeze strength in both the left and right hands. Participants begin by standing upright with their feet positioned shoulder-width apart. Subsequently, one hand grips the dynamometer in a straight position beside the body, with the palm facing toward the thigh and the dynamometer handgrip facing outward. The individual then pulls the dynamometer hand grip lever with maximum force. It is important to ensure that the hand holding the dynamometer handgrip remains straight and does not make contact with any other objects. This test may be repeated twice, with the highest recorded value in kilograms being considered each time. Both hands undergo the same test using the Handgrip Dynamometer Right (HD R) and Handgrip Dynamometer Left (HD L).

Sit and Reach (S&R)

The sit and reach test are used to assess flexibility performance. The athletes sit with their feet about hip-width apart against the testing box. Knees are stretched, right hand over left, and they gently reach forward as far as they can by sliding their hands over the measurement board. Participants get two opportunities to carry out this test and the best result from this test will be chosen.

Statistical analysis

The data analysis approach in this study includes: (1) a description test; (2) a normality test, employing the Shapiro-Wilk test to assess the normality of the data distribution; and (3) the homogeneity test was utilized to determine the uniformity of variations in the population. This test used Levene's Test with the F test to examine the comparability of variances in the pretest and posttest experimental group data. It was carried out to ascertain whether the data distribution (variance) of the two experimental groups was homogeneous and balanced for comparison. If the Levene test findings indicate a significance value of $p>0.05$, the data distribution (variance) of the two experimental groups is considered homogeneous (4). To identify any differences in variables between the pretest and posttest in the experimental group, a t-test was conducted. A significance value smaller than 0.05 ($P < 0.05$) indicates a distinction in the results of the analysis. The pretest and posttest data underwent statistical discrete analysis using the t-test and version 27 of SPSS, with the significance level set at 5% (equivalent to 0.05). The effect scope was assessed using Cohen's d-test subsequent to the t-test analysis, both before and after the implementation of the intervention. The criteria used to evaluate the magnitude of ES (Hopkins, Marshall, Batterham, & Hanin, 2009) were: small effect= 0.2; medium effect= 0.5, and large effect= 0.8.

Table 2. Comparison of anthropometric data between the pre- and post-groups

Variables	Experimental Group (n = 12)				Control Group (n = 12)			
	Pre-Training Mean±SD	Post Training Mean±SD	p	E.S.	Pre-Training Mean±SD	Post Training Mean±SD	p	E.S.
Body Mass (kg)	76.46±7.08	74.58±7.56	0.003	1.11	74.65±8.67	74.33±8.84	0.078	0.55
Body Fat (%)	17.85±3.45	16.31±3.2	0.000	1.69	17.37±3.39	17.36±3.60	0.952	0.06
Height (cm)	181.67±6.09	–	–	–	179.25±8.13	–	–	–

Results

The body composition of the two groups at the commencement and conclusion of the intervention is presented in Table 2. The experimental group exhibited statistically significant variations in body mass and body fat. In contrast, the control group exhibits negligible alterations across all variables.

Based on measurements of the athlete's power, strength, and flexibility abilities before and after being given strength training treatment, a statistical picture was obtained as shown in Tables 3 and 4.

Table 3. Statistical Description of Pre-Test Score

Groups	Variables	Pre-test			
		Mean	SD	Min	Max
EG	HD (L)	44.80	8.37	30.70	55.30
	HD (R)	46.81	6.44	37.00	54.00
	VJ	23.00	2.82	19.60	28.90
	S&R	32.40	3.40	26.40	37.30
	LD	184.58	46.20	135.00	295.00
	BD	120.41	12.37	100.00	150.00
CG	HD (L)	37.45	6.62	29.00	51.00
	HD (R)	40.30	5.99	31.00	48.00
	VJ	20.32	3.19	17.00	26.20
	S&R	29.44	2.29	25.00	32.00
	LD	130.83	34.59	90.00	200.00
	BD	100.75	22.16	52.00	132.00

Table 4. Statistical Description of Post-Test Score

Groups	Variables	Post-test			
		Mean	SD	Min	Max
EG	HD (L)	49.49	11.23	25.00	65.30
	HD (R)	52.68	5.34	43.90	60.20
	VJ	26.64	2.34	22.30	30.10
	S&R	35.90	3.30	30.00	40.20
	LD	193.91	46.06	140.00	300.00
	BD	127.33	12.66	103.00	152.00
CG	HD (L)	37.63	6.31	30.00	49.90
	HD (R)	42.40	5.73	30.80	49.50
	VJ	23.59	4.27	17.50	29.70
	S&R	30.93	3.92	23.00	36.20
	LD	130.91	36.45	199.00	93.00
	BD	103.25	22.16	24.06	135.00

Normality results

The normality test used the Shapiro-Wilk test. Table 5 explains that all data were normally distributed because all results have significant values > 0.05.

Table 5. The Normality Test Results

Groups	Variables	Pre-test		Post-test	
		s-w	P	s-w	P
EG	HD (L)	0.923	0.313	0.946	0.581
	HD (R)	0.874	0.074	0.915	0.246
	VJ	0.895	0.136	0.936	0.446
	S&R	0.966	0.865	0.935	0.433
	LD	0.888	0.112	0.911	0.218
	BD	0.923	0.312	0.978	0.972
CG	HD (L)	0.940	0.503	0.931	0.392
	HD (R)	0.927	0.349	0.946	0.584
	VJ	0.869	0.064	0.924	0.325
	S&R	0.886	0.105	0.941	0.507
	LD	0.932	0.406	0.897	0.146
	BD	0.906	0.188	0.874	0.073

Homogeneity results

The homogeneity test used the Levene Statistics test. Table 6 explains that all data were homogeneously distributed because all results obtained significant values > 0.05.

Table 6. The Homogeneity Test Results

Groups	variables	Levene Statistic	P
EG	HD (L)	0.637	0.433
	HD (R)	1.616	0.217
	VJ	0.582	0.454
	S&R	0.105	0.749
	LD	0.005	0.944
	BD	0.062	0.805
CG	HD (L)	0.001	0.982
	HD (R)	0.082	0.777
	VJ	2.394	0.136
	S&R	3.740	0.066
	LD	0.098	0.758
	BD	0.010	0.923

Hypothesis Testing

After the data passed the prerequisite tests and all data were normally and homogeneously distributed, hypothesis

Table 7. The Hypothesis Test Results

Variables	Indicators	EG				CG			
		Mean	t count	P value	ES	Mean	t count	P value	ES
Strength	HD (L)	4.68	2.931	0.014	0.85	0.175	0.166	0.871	0.05
	HD (R)	5.86	4.559	0.001	1.32	2.10	2.007	0.070	0.58
	LD	9.33	6.143	0.001	1.77	0.083	0.057	0.956	0.02
	BD	6.91	4.368	0.001	1.26	2.50	1.764	0.105	0.51
Flexibilities	S&R	3.50	4.868	0.000	1.41	1.49	1.780	0.103	0.51
Power	VJ	3.64	4.541	0.001	1.31	3.27	3.467	0.005	1.00

testing was carried out. The objective of this research was to assess the impact of an eight-week strength training regimen, conducted during a specific preparation phase, on the physical performance of male junior volleyball players. The outcomes of the Paired Sample T-test, which was employed to address the research hypothesis, are as follows.

The experimental group experienced a substantial increase in the strength, flexibility, and power variables, as evidenced by the positive t-statistic and sig value (both less than 0.05) in Table 7. Additionally, Table 7 demonstrates that the strength, flexibility, and power variables in the control group did not experience a statistically significant increase (sig < 0.05). Thus, it can be concluded that strength training for 8 weeks, which was carried out at a specific preparation phase for the performance of junior male volleyball athletes, was proven to significantly increase the performance of junior volleyball athletes with an effect size in the large effect category.

Discussion

The study's main findings revealed notable differences in strength, flexibility, and power between the experimental group and the control group. Specifically, the experimental group demonstrated significant increases in HDL ($p = 0.014$), HDR ($p = 0.001$), LD ($p = 0.001$), BD ($p = 0.001$), S&R ($p < 0.001$), and VJ ($p = 0.001$). In contrast, the control group only exhibited a significant increase in the power or VJ variable ($p = 0.005$), with no significant increases observed for HDL ($p = 0.871$), HDR ($p = 0.070$), LD ($p = 0.956$), BD ($p = 0.105$), and S&R ($p = 0.103$). Both groups experienced a significant enhancement in the power or VJ variable, yet the experimental group's improvement surpassed that of the control group ($p = 0.001$ and $p = 0.005$, respectively). Consequently, the combination of technical/tactical training, friendly matches, and resistance training was found to be more effective in enhancing HDL, HDR, LD, BD, S&R, and VJ compared to technical/tactical training and friendly matches alone. On the other hand, engaging in only technical/tactical training and friendly matches was sufficient to enhance VJ, although this approach was not as effective as combining it with resistance training.

Haff and Triplett (2015) state that resistance training can enhance strength by promoting neuromuscular adaptation, which is contingent upon the intensity of heavy load training. This adaptation leads to improved muscle function and the ability to generate greater force. Jenkins et al. (2017) support the neuromuscular adaptation theory, demonstrating that a 6-week resistance training program using an 80% 1RM load can enhance neural adaptation by increasing neural drive and muscle activation efficiency, resulting in greater strength gains compared to training with a 30% 1RM load. Additionally, the study suggests that gradually increasing the intensity of the exercise program contributes to similar adaptations, as evidenced by significant improvements in muscle strength in both pre-test and post-test assessments.

Various studies have shown that resistance training leads to a more significant increase in muscle strength when the training load is in the strength zone, typically exceeding 80% of 1 RM (>8 RM), compared to lower loads (Schoenfeld, Grgic, Van Every, & Plotkin, 2021). In the present study, the EG group experienced a significant increase in muscle strength following a resistance training program with light to moderate intensity (40-80% of 1 RM). Furthermore, research by Lopez et al. (2021) supports these findings by explaining that selecting a moderate load intensity (9-15 RM) is also effective in increasing muscle strength, particularly for individuals who may not tolerate heavy loads.

Strength training's impact on an athlete's flexibility is a well-documented topic (Kumar & Zemková, 2022). Flexibility, defined as the muscles' ability to stretch optimally across joints, is typically assessed through ROM (Ratamess, 2021). Despite this, the mechanisms through which resistance training influences flexibility remain a subject of widespread debate. Nonetheless, the results of this study reveal a statistically significant improvement in flexibility indicators within the experimental group compared to the control group. These findings align with the research conducted by Afonso et al. (2021) and several other studies included in their systematic review and meta-analysis, which have demonstrated that both resistance training and stretching exercises can enhance ROM. However, the specific reasons behind why resistance training enhances ROM remain unclear, possibly due to variations in contraction types, exercises, modalities, and training regimens. One compelling rationale for the increase in ROM through resistance training is its ability to induce architectural changes in muscles, as evidenced by an increase in fascicle length when exercises are performed with full ROM (Gérard et al., 2020). Furthermore, according to Valamatos et al. (2018), strength training can contribute to muscle lengthening, particularly when exercises are executed through the full range of motion. This allows the muscles to stretch and thereby enhance flexibility.

The use of free weight and machine-based resistance training programs in the resistance training program of this

study may have contributed to its impact on flexibility. It is postulated that the notable outcomes observed in the large experimental group are attributed to the incorporation of free resistance training. Free resistance training enables exercises with a wider range of motion compared to machine-based training. This notion is supported by Behm (1995), who suggests that calisthenic or machine-based resistance training may not yield the same effect in increasing range of motion as free resistance training. It is important to underscore the need for further research on the effects of resistance training with different training modalities.

According to Caputo et al. (2017) an increase in strength is linked to a decrease in pain. Consequently, reduced sensitivity to muscle pain may contribute to the improvement in range of motion (ROM). Additionally, there is a theory suggesting that an increase in agonist-antagonist muscle coactivation can influence the mechanism through which resistance training enhances ROM by promoting a better or more balanced force ratio (Wyon, Smith, & Koutedakis, 2013). Given that weak muscle strength is associated with a reduction in ROM (Frasson et al., 2020), it follows that resistance training, which primarily aims to enhance muscle strength, can concurrently increase ROM (Moscão, Vilaça-Alves, & Afonso, 2020).

It is crucial to recognize that the extent of the effect on flexibility may be shaped by the particular type of strength training chosen and how it is carried out. Strength training involving full range of motion typically proves to be more effective in enhancing flexibility, as evidenced in this study. Furthermore, the researchers suggest the inclusion of specific flexibility exercises in the training program to achieve the best possible results.

Currently, there is a research trend focusing on plyometric training and its impact on power performance in various sports for increasing athlete power (Silva et al., 2019). Numerous studies indicate that plyometric training is an effective exercise for optimizing athlete power compared to other forms of training. In addition to plyometric training, several studies have shown significant increases in power through vertical jump (VJ) when combining resistance training loading in one session with contrast strength training (Cormier, Freitas, Rubio-Arias, & Alcaraz, 2020; Hammami, Gaamouri, Shephard, & Chelly, 2019; Schneiker, Fyfe, Teo, & Bishop, 2023). Interestingly, our study revealed that resistance training combined with volleyball skills training alone (EG), or skills training alone (CG), were sufficient to enhance athletes' power, as evidenced by the VJ results, without involving plyometrics or contrast training methods. The increase in power in the EG group may be attributed to the notable improvement in muscle strength test results. According to Taber et al. (2016), the foundation for developing power lies in maximum strength. Therefore, the substantial increase in power in the EG group, compared to the CG, was likely due to a greater potential to develop power through increased muscle strength.

Moreover, the researchers believe that the enhancement of power can occur through a combination of resistance training and volleyball skill training, as this training provides athletes with the opportunity to translate their muscle strength into vertical jumping and other volleyball skills such as blocking, jump serve, spikes, and other movements involving jumping. Additionally, the power exhibited by the EG group may also have been influenced by decreased changes in body mass at the end of the intervention in this study. It is known that lower body mass is associated with improved vertical jump performance in volleyball players compared to those with higher body mass, as indicated by BMI (Nikolaidis, 2013). Supported by the research of Ben Brahim et al. (2023), BMI is a fairly strong predictor in determining vertical jump test performance.

In contrast, even though there was no significant change in body mass between the pre-test and post-test results of the CG group, the increase in power in this group may have been a result of improved vertical jumping performance due to volleyball skills training. The proficient execution of jumping movements in technical/tactical training within the CG group could be the primary reason for the observed increase in VJ performance. Put differently, it is highly probable that this increase is significantly influenced by the enhancement of the athlete's jumping technique or jumping quality, rather than directly from an increase in power.

In general, strength training can enhance strength, flexibility, and muscle power when the training program is specifically tailored to facilitate adaptation in these areas. Developments in all these components adhere to the principle of specificity, which dictates that the body will adapt to training based on the manner in which it is trained (Reiman & Lorenz, 2011). Furthermore, the training program employed in this study is a specific preparatory training program aimed at enhancing physical abilities tailored to the demands of volleyball and in support of volleyball movements. While general preparatory training places greater emphasis on exercises prepared for the athlete's physical adaptation to training, specific preparatory training is dedicated to providing opportunities for athletes to integrate physical abilities with volleyball movements. It is important to note that the effects of strength training on strength can vary depending on various factors, including training intensity, volume, frequency, execution technique, and individual genetics. A well-designed strength training program takes all of these factors into account to achieve optimal results. Meanwhile, further research into the impact of resistance training regimens on the adaptation of volleyball athletes' physical abilities requires additional investigation.

This study aimed to provide valuable insights for the selection of resistance training during the specific preparatory phase and as a foundation for further research. Furthermore, the researchers advocated for greater emphasis on resistance training programs, particularly during the specific preparatory phase. Implementing resistance training during this phase enables athletes to optimize their muscle strength and flexibility compared to those who only engage in resistance training during the general preparatory phase. Moreover, achieving a balance between strength and flexibility is crucial for an athlete's performance. Well-rounded strength training combined with flexibility exercises can aid in injury prevention and enhance overall athletic performance. Furthermore, the harmonious development of strength and flexibility may be fundamental to improved power performance.

While this research presents a novel contribution to the existing body of knowledge, it is not without limitations. Firstly, the scarcity of relevant studies investigating resistance training alongside technical and tactical training in volleyball posed challenges in comparing the findings with those of

another research. Most existing research primarily focuses on resistance training combined with plyometric training. Secondly, the results should ideally have been confined to a comparable sample of participants. A comprehensive comprehension of strength training requires a grasp of anatomy, human physiology, and neuromuscular adaptation. Additionally, this research lacked a comparison of the technical abilities and performance of junior male volleyball athletes, which could be valuable for future investigations given the potential variations in the implementation of volleyball strategies and tactics among junior athletes. Moreover, comparisons between other periods, such as the specific preparatory and pre-competition periods, were not conducted. Notably, the athletes in this study had undergone general preparatory phase resistance training, underscoring the need for a brief overview of the necessity of specific preparatory resistance training. For future research, it may be necessary to conduct a comparison between resistance training alone, combining resistance training with skill and tactical exercises in volleyball, and skill and tactical training alone. Additionally, a comparison with plyometric training may also be warranted. Such comparisons could potentially reveal differences in adaptive responses and training effects. Lastly, the sample sizes for each group were relatively small, indicating that this study remains in its preliminary phase. Recruiting a substantial sample within this age cohort is challenging and nearly unattainable. Therefore, the researchers recommend that future research give careful consideration to the limitations identified in this study.

Conclusions

The researchers concluded that strength training, when incorporated into volleyball training, especially at specific preparation phases, can increase power, strength, and flexibility. Incorporating targeted stimuli, such as strength training, into training sessions can promote continuous progressive neuromuscular adaptation and be a safe training modality for this age group. To optimize the performance of junior volleyball players, coaches should incorporate specific strength training, such as integrating strength training with technical and tactical training during the specific preparation phase. In addition, these results suggest that coaches should consider specific adaptations when developing training programs for volleyball players with the goal of enhancing their athletic performance; this may necessitate a tailored approach to program design.

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Conflict of interest

The authors guarantee that no conflicts of interest exist.

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Вплив 8-тижневого силового тренування на етапі спеціальної підготовки на показники результативності волейболістів чоловічої статі

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 9 с., 7 табл., 33 джерела.

Історія питання. Тренувальні програми є частиною забезпечення навчального процесу, що потребує правильної та коректної підготовки та реалізації.

Мета дослідження. Метою дослідження була оцінка впливу 8-тижневої програми силових тренувань, проведеної на певному етапі підготовки, на показники результативності волейболістів чоловічої статі юнацького віку.

Матеріали та методи. Даний аналіз був проведений у якості експериментального дослідження, у якому взяли участь 24 волейболісти чоловічої статі ([середній ± СВ] вік: 17,96 ± 1,23 років; маса тіла: 75,56 ± 7,80 кг; зріст: 180,46 ± 7,14 см; вміст жиру в організмі: 17,62 ± 3,36%), які були рандомізовані до експериментальної групи (ЕГ): n = 12, та контрольної групи (КГ): n = 12. Програма тренувань тривала вісім тижнів і проходила на спеціальному підготовчому етапі.

Результати. В експериментальній групі після восьми тижнів силових тренувань спостерігалося суттєве зростання показників динамометрії лівої руки ($p<0,014$), динамометрії правої руки ($p<0,001$), вертикального стрибка ($p<0,001$), тесту на гнучність sit-and-reach (спосіб вимірювання загальної гнучкості тіла при згинанні тулуба вперед, сидячи на підлозі з витягнутими вперед руками) ($p<0,000$), динамометрії ніг ($p<0,000$) і динамометрії м'язів спини ($p<0,001$).

Висновки. При впровадженні силових тренувань до програми підготовки волейболістів, вони можуть покращити показники результативності, сили та гнучкості, особливо, якщо їх проводити на певному етапі підготовки. Включення цілеспрямованих стимулів, таких як силові навантаження, до тренувальних занять є безпечним методом тренування для даної вікової групи і може сприяти безперервному та поступовому поліпшенню адаптації нервово-м'язової системи.

Ключові слова: волейбол, результативність, силове тренування.

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The Relationship of 2D:4D Finger Length Ratio with Biomotoric Characteristics and Sports Performance in Adolescent Basketball Players

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Abstract

Background. The aim of this study is to determine the relationship of 2D:4D finger length ratio (also known as digit ratio) with biomotoric features and sports performance in adolescent basketball players. 24 male basketball players with a mean age of 14.83±0.71 years and a training age 7.08±1.92 years participated in the study.

Materials and methods. The participants' 2D and 4D finger lengths of both hands, height (cm), body weight (kg), some biomotoric characteristics and sports performances were determined by measurements. The German Heidelberger Basketball Test was conducted to evaluate the basketball-based sports performances of the participants. The SPSS 25.0 package program was performed in the statistical analysis of the obtained data. The Shapiro-Wilk test was used to determine whether or not the data showed a normal distribution. Parametric tests were preferred for statistical analysis as the data were found to have a normal distribution.

Results. It was found that there was no statistically significant relationship between the 2D:4D finger length ratio, some motoric features and basketball-based sports performances of the participants ($p>0.05$). It was concluded that the ratio of 2D:4D finger lengths in adolescent basketball players did not have an effect on biomotoric features and basketball-based sports performance. When the correlation between 2D:4D finger length ratio and sports performance parameters was examined, no statistically significant relationship was observed ($p>0.05$).

Conclusions. Although some studies show a significant negative correlation between performance tests and the 2D:4D ratio, it should be noted that the 2D:4D finger ratio is not the only determinant for sports performance.

Keywords: basketball, 2D:4D finger lengths, biomotoric features, sports performance.

Introduction

Tests conducted to identify individuals with a predisposition for sports or a sports-oriented mindset include both physical and psychological assessments, starting from the early years of life. Among these tests, anthropometric measurements play a significant role in determining individuals' physical capacities. The ratio of the length of the index finger (2D) to the length of the ring finger (4D), known as the 2D:4D ratio, is a measurement frequently used in recent academic studies. The 2D:4D finger length ratio, indicative of the amount of testosterone exposure in the womb, does not change during pregnancy and adulthood (Richards et al., 2022).

The 2D:4D finger length ratio has been used as an indicator of prenatal exposure to testosterone in the fields of health, behavior, and sports science. It has been proposed that prenatal androgens influence the developing brain in later stages of life by increasing sensitivity to testosterone, regulating the structure and function of the brain. It has also been suggested that the 2D:4D finger length ratio could contribute as a reliable indicator of athletic potential (Reed & Meggs, 2017; Alonso et al., 2018). However, this

situation should not be perceived as the sole indicator of performance. When used in conjunction with other analyses, it can be considered as a measure of success or motivation. Additionally, elevated fetal androgen levels have been associated with the development of cardiovascular systems, good visual-spatial abilities, physical endurance, speed, and an inclination towards agile behaviors that may be helpful in sports (Manning & Fink, 2018).

Prenatal testosterone levels can be a fundamental precursor to success in certain sports activities. This is because structural and functional characteristics altered by testosterone activity, such as muscle fiber hypertrophy, increased strength, decreased fat mass, and elevated hematocrit, can contribute to an athlete's success (Moffit & Swanik, 2011). The 2D:4D finger length ratio has been found to impact performance in various individual and team sports, including basketball (Frick et al., 2017), volleyball (Panda et al., 2014), and soccer (Nobari et al., 2021). In a group consisting of judo athletes, Olympic wrestlers, and kickboxers, the 2D:4D finger length ratio was significantly lower compared to a control group that did not engage in sports (Adamczyk et al., 2021).

Basketball, by its characteristic nature, encompasses both aerobic and anaerobic activities, including walking, standing, and moderate to low-intensity runs. In basketball, fundamental skills such as rebounding, blocking, and shooting often involve elements like jumping, quick turns, and dribbling (Pliauga et al., 2015). Due to its complex nature, basketball performance can be influenced by numerous factors such as age, gender, genetics, kinanthropometric characteristics, endocrine system, autonomic nervous system, biological rhythms, psychological state, climate-environmental conditions, injuries, and illnesses. It is believed that one of these factors is the 2D:4D finger length ratio. Therefore, it is considered that this research aims to determine the relationship between the 2D:4D finger length ratio and athletic performance in adolescent basketball players. It is thought that such studies are important for predicting the level of physical development in adolescents based on prenatal sex hormones and can contribute to the selection of qualified athletes.

Materials and methods

Study participants

The sample of this study consisted of 24 male basketball players with an average age of 14.83±0.71 years and a training age of 7.08±1.92 in Incirliova district of Aydin province.

Study organization

Height and body weight measurements

The height of the participants was determined by measuring the distance between the heel tip and the top of the head vertically on a flat surface with bare feet with a stadiometer. The body weights of the participants, who were barefoot, were measured with a scale (Lopez-Peralta et al., 2022).

Body mass index

Body Mass Index (BMI) ratios of the participants were calculated using the formula below (Pantanowitz, 2021).

Body Mass Index (BMI) = Weight (kg) / Height (cm^2)

Determination of age and training age

Personal statements were taken as the basis to determine the age and training age of the participants.

Flexibility

The flexibility of the participants was determined by the sit-and-reach test. Participants were asked to recline the soles of their feet against the sit-down table and keep their legs stretched. While the participants kept their desired positions, they stretched out as far as they could by extending both hands towards the sit-down table. The distance that the participants, who waited for 2 seconds at the last point they could reach, was recorded in cm. After two measurements were performed, the best grades of the participants were recorded in cm (Nokariya et al., 2023).

Static force

The handgrip strength test was conducted to determine the static strength of the participants. A dynamometer was utilised in the application of the test. In the anthropometric stance, the participants positioned the dynamometer appropriately on the thumb palm, and then grasped it to cover the other four fingers. When the participants were ready, they squeezed the dynamometer for 5 seconds with maximum effort. After three trials for each hand were performed, the best result was recorded in kilograms (Kociuba et al., 2019).

Anaerobic power

The standing long jump test was performed to determine the anaerobic power of the participants. In this test, the participants got position on a flat and smooth surface with the feet together behind the marked line and the toes behind the jump line. When the participants felt ready, they tried to jump to the furthest point by throwing their arms forward and pulling their knees towards them. The distance between the starting line and the participant's closest standing to the line after jumping was measured. The test was performed twice for each participant. The best grade of the participants was recorded in centimetres (Laurson et al., 2022).

Abdominal muscle endurance

The participants' abdominal muscle endurance was determined by 30-second push-ups. The test was performed on a flat surface. They positioned their hands and toes on the floor. During the test, they paid attention to keep the feet open, arms shoulder-width apart, and the trunk to be upright. After they kept their back and knees straight, they decreased their chest towards the ground, then they pushed the floor with their hands and lifted the chest up again. The test continued for 30 seconds. They were asked to reach the maximum number of push-ups they could achieve in 30 seconds. The number of completed push-ups in accordance with the test protocol was recorded after the test (Hashim et al., 2018).

Agility

The t-test was utilised to determine the agility of the participants. The test area consisted of four contact areas in the shape of the letter T which was 10 meters long and 10 meters wide. The participants were asked to complete the track, which required movements in different directions, as soon as possible. After the test was performed twice, the best time was recorded in seconds (Raya et al., 2013).

2D and 4D finger length measurement and ratio

The area between the basal line on the proximal part of the finger and the pulp on the palmar surface of the hand

was measured in centimetres with a Vernier caliper that can measure up to 0.05 millimetres. Measurements were performed twice by the same person for reliability. The 2D:4D finger length ratio was determined by dividing the second finger length by the fourth finger length (Wu, 2013).

German Heidelberger Basketball Test

The Heidelberger Basketball Test was developed in 1987 by the collaboration of the scientists of the Sports Institute in Heidelberg and basketball coaches. This test has the capability of evaluating basic basketball-specific skills. The rest periods between measurements to evaluate different technical skills vary between 2 and 3 minutes (Alpullu & Bozkurt, 2018).

Lay up shot

The participants were asked to perform the right layup first, then the left layup for 1 minute, starting from the free throw line, and to bounce the ball to the free throw line after each layup. The participants were given two chances. The score obtained from the attempt in which the most successful shot was performed was recorded (Özçelik & Alpullu, 2019).

Shooting from the Paint

The areas from which shots were performed were divided into 4 equal parts with funnels. The participants started shooting for 1 minute with the command. They were asked to follow their balls for the missed shots, to rebound the ball and to shoot again. The shots that passed through the circle were considered as scores. The participants were given two chances. The best score obtained from the trials was recorded (Özçelik & Alpullu, 2019).

Slalom dribbling

Ten slalom sticks were arranged in intervals of 2m-1m-1m-2m-1m-1m-4m-1m-1m from the starting. The participants were asked to dribble back and forth between slalom bars. They were given three chances. The best score obtained from the trials was recorded (Özçelik & Alpullu, 2019).

Passing test

Two squares with 30 centimetres side length were designed on the wall with tapes. The distance between the two squares was 1.80 cm and the height from the ground was 1.50 cm. The tape, which was 2 meters away from the wall, was set up on the floor of the hall. Two funnels were placed at 1-meter intervals on the tape. The participants were asked to throw the ball to the target with the command and to dribble to the other funnel with the outer hand by taking the ball back. They were asked to carry out as many tasks as possible for 30 seconds. The accurate shots within 30 seconds were considered acceptable. They were given two chances. The best score obtained from the trials was recorded (Özçelik & Alpullu, 2019).

Statistical analysis

The data obtained from the measurements and the personal statements of the participants were evaluated at the 0.05 significance level in the SPSS 25.0 package program. The Shapiro-Wilk test was performed to determine whether the data indicated normal distribution or not. Since it was perceived that the data showed a normal distribution, Pearson correlation analysis was conducted to examine the relationship of the 2D:4D finger length ratios of the participants with their biomotoric characteristics and basketball-specific performance values.

Results

Table 1 showed the descriptive statistics of the adolescent basketball players who generated the sample of the research.

Table 1. Descriptive statistics on participants

Variables	n	Mean	SD	Min	Max
Height (cm)	24	1.81	0.06	1.74	1.90
Body weight (kg)	24	76.85	13.71	60	100
Body mass index (kg/cm^2)	24	23.42	4.33	16.74	31.61
Age (years)	24	14.83	0.71	14	16
Training age (years)	24	7.08	1.92	3	9

When Table 2 was examined, it was observed that there was no statistically significant relationship between the right and left hand 2D:4D finger length ratios and biomotoric characteristics of the participants (p>0.05).

Table 2. The relationship between 2D:4D finger length ratio and biomotoric features

Variables	Right hand 2D:4D ratio		Left hand 2D:4D ratio	
	r	p	r	p
Flexibility	-0.443	0.149	0.168	0.602
Right static force	-0.334	0.289	0.161	0.617
Left static force	-0.410	0.185	0.016	0.961
Anaerobic power	-0.199	0.536	0.158	0.625
Abdominal muscle endurance	-0.215	0.501	-0.025	0.938
Agility	0.003	0.994	0.112	0.728

Table 3. showed that there was no statistically significant relationship between the right and left hand 2D:4D finger length ratios and basketball-based sportive performances of the participants (p>0.05).

Table 3. The relationship between 2D:4D finger length ratio and sportive performance

Variables	Right hand 2D:4D ratio		Left hand 2D:4D ratio	
	r	p	r	p
Lay up shot	-0.499	0.099	-0.258	0.417
Shot	-0.016	0.962	-0.182	0.571
Dribbling	0.123	0.704	0.174	0.588
Pass	-0.453	0.139	-0.233	0.466

Discussion

The study, which was conducted to examine the relationship of 2D:4D finger length ratio with biomotoric characteristics and sportive performance in adolescent basketball players, indicated that there was no significant relationship between 2D:4D finger length ratio and

sportive performance. That condition can be explained by the fact that the participants generating the sample of the study were in the adolescence period and their bone development processes were continuing, as they had not yet completed their adulthood. Because the physical growth and development, which slows down partially in advanced childhood, accelerates again in adolescence and reaches its adult structure at the end of this period. In a similar study, Acar & Eler (2018) suggested that finger length ratio was determined in the mother's womb, and did not have an effect on sportive performance since it did not change during adolescence and adulthood.

This study showed that there was no relationship between the 2D:4D finger length ratio and the static strength of the right and left hands. In the other study supporting this study, Eghbali (2016) suggested that there was no significant relationship between 2D:4D finger length ratio and handgrip strength among master athletes.

In this study, when the relationship between 2D:4D finger length ratio and biomotoric features was examined, no correlation was observed among flexibility, right static strength, left static strength, anaerobic power, abdominal muscle endurance and agility. In another study that has similar characteristics to the findings obtained in this study, Peeters et al. (2013) observed that there was no significant relationship between the left hand 2D:4D finger length ratio and any physical fitness components (balance, limb movement speed, flexibility, explosive strength, static strength, trunk strength, functional strength, running speed / agility and endurance). In his study on basketball players, Güler (2018) indicated that there was no significant relationship between 2D:4D finger length ratio and abdominal muscle endurance (push-ups), vertical jump (cm), anaerobic power (kg/min/sec) and aerobic capacity (ml/kg/min). In their study, in which Mehdizadeh et al. (2013) suggested that that there was no significant correlation between 2D:4D finger length ratio and dynamic muscular endurance (pull-ups and chinning bars), they concluded that muscular endurance cannot be predicted by anthropometric dimensions.

Contrary to all these studies, some studies reported that there was a negative relationship between sportive performance and 2D:4D finger length ratio among male and female athletes. The ratio of the index finger to the ring finger was negatively related to the amount of testosterone in the blood (Acar & Eler, 2018; Eklund, 2020).

In their study, in which Bilgiç et al. (2016) examined the relationship between 2D:4D finger length ratios and sportive performance among 11-13 year old children from different sports branches, they determined that there was a positive correlation between right and left hand 2D and 4D finger length ratios and anaerobic capacity. In a similar study, Köroğlu et al. (2016) stated that there is a positive correlation between finger length and the dominance of testosterone hormones. They mentioned that athletes with longer 4D finger length exhibit higher anaerobic power performance.

Conclusion

Within the light of these findings, this study concluded that the ratio of 2D:4D finger lengths in adolescent basketball players did not have an effect on biomotoric characteristics and basketball-based sportive performance. However, when the results obtained in scientific studies that were conducted with the participation of athletes from different age and branch groups were considered, the study predicted that the 2D:4D finger length ratio of adults might affect biomotoric characteristics and sportive performance. Furthermore, the study remarks that the ratio of 2D:4D finger lengths will be insufficient to correlate with sportive performance.

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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Взаємозв'язок пальцевого індексу 2D:4D з біомоторними характеристиками та спортивними показниками у баскетболістів підліткового віку

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 6 с., 3 табл., 28 джерела.

Вступ. Мета цього дослідження полягає у визначенні зв'язку співвідношення довжини вказівного і безіменного пальців (пальцевого індексу) 2D:4D з біомоторними особливостями та спортивними показниками у баскетболістів підліткового віку. У дослідженні взяли участь 24 баскетболісти чоловічої статі, середній вік яких становив 14,83±0,71 років, а вік тренувань — 7,08±1,92 років.

Матеріали та методи. За допомогою вимірювань визначали довжину 2-го і 4-го пальців обох рук, зріст (см), масу тіла (кг), деякі біомоторні характеристики та показники спортивної результативності учасників дослідження. Для оцінки спортивної результативності учасників був проведений німецький баскетбольний тест Гайдельберга (Heidelberger Basketball Test). Статистичний аналіз отриманих даних проводився за допомогою програми SPSS 25.0. Для визначення відповідності даних до нормального розподілу використовувався критерій Шапіро-Уілка. Для статистичного аналізу перевага надавалася параметричним тестам, оскільки було встановлено, що дані мають нормальний розподіл.

Результати. Встановлено, що не було статистично значущого зв'язку між пальцевим індексом 2D:4D, деякими характеристиками рухових якостей та спортивними показниками з баскетболу серед учасників дослідження ($p>0,05$). Було зроблено висновок, що пальцевий індекс 2D:4D у баскетболістів підліткового віку не впливає на біомоторні особливості та спортивну результативність у баскетболі. При дослідженні кореляції між пальцевим індексом 2D:4D та параметрами спортивної результативності не спостерігалося статистично значущого зв'язку ($p>0,05$).

Висновки. Незважаючи на те, що деякі дослідження показують значну негативну кореляцію між тестами на продуктивність і співвідношенням 2D:4D, слід зазначити, що пальцевий індекс 2D:4D не є єдиним визначальним фактором для визначення спортивної результативності.

Ключові слова: баскетбол, довжина пальців 2D:4D, біомоторні особливості, спортивна результативність.

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High School Student-Athletes: Their Motivation, Study Habits, Self-Discipline, Academic Support, and Academic Performance

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Abstract

Study purpose. Student-athletes have a role that is not easy to balance between the role of being an athlete and the role of being a student at school. Not a few of them have obstacles in balancing both roles. This study aims to reveal the characteristics of secondary school student-athletes in Bengkulu City. The main objectives are to describe the level of achievement motivation, study habits, self-discipline, academic support, and academic performance.

Materials and methods. This study is a quantitative descriptive research with a survey approach involving 402 student-athletes at the junior high school and senior high school levels. The student-athletes represent 16 sports. The average age of student-athletes is 15.9 years. The instrument used in the study was a questionnaire consisting of 36 statement items. The mean ideal and standard deviation ideal formulas were used to analyze data regarding the category level of each indicator, while the independent sample t-test was used to determine differences in data between student-athletes based on gender and type of sport.

Results. The results of this study reveal that student-athletes in Bengkulu City have achievement motivation, study habits, self-discipline, academic support, and academic performance in the high category. There is a significant difference between male and female student-athletes (sig 0.001 < 0.005). There were no significant differences between student-athletes from individual and team sports (0.442 > 0.005).

Conclusions. Student-athletes at junior high school and senior high school education levels have good characteristics, there are significant differences between male and female athletes, and there are no significant differences between individual athletes and team athletes.

Keywords: student-athletes, motivation, habits, discipline, academic.

Introduction

Education at the high school level is a critical period in students' development, where they not only pursue academic excellence but also engage in various extracurricular activities for skill and character development (O'Neil et al., 2021). One group of students who fulfill dual roles are student-athletes, who try to maintain a balance between sports performance and academic achievement (Kristiansen, 2017). Sports in high school are not just physical activities, but also an important tool in developing character, leadership, and interpersonal skills (DÜZ & ASLAN, 2020). Through sports, students can learn about teamwork, responsibility, and discipline (de Prada Creo et al., 2021). Therefore, it is important to understand how involvement in sports at the secondary school level can influence important aspects of education, such as motivation, study habits, and academic

achievement (Escosio Suguis & Suraya Belleza, 2022). Student-athletes at the high school level often face different challenges compared to those at lower levels of education due to academic demands and pressure to succeed in various fields (Chrisman et al., 2013).

Motivation is a key factor in understanding student-athlete engagement in high school (Xie et al., 2020). Intrinsic motivation, which comes from internal drives such as the desire to achieve excellence, and extrinsic motivation, which comes from external drives such as recognition or rewards, can play an important role in determining the extent to which students engage in sports and excel academically (Howard et al., 2021). Various previous relevant studies have been conducted by researchers including (Lupo et al., 2015) which revealed that student-athletes have high motivation to pursue two careers, namely a career as an athlete and a career as an athlete. Similar research was also conducted (Yukhymenko-Lescroart, 2018) which revealed that student-athletes motivation to take part in sports was influenced by intrinsic interest, while student-athletes motivation to take academic classes was influenced by the grades obtained in class. In their research (Quinaud et al., 2020) it was revealed that the level of education and training hours have a big influence on athlete motivation.

It is important to dig deeper into the study habits of student-athletes because effective study habits can be the foundation of their academic success (Brecht & Burnett, 2019). Implementing good study strategies, managing time wisely, and having a strong focus can help student-athletes achieve a healthy balance between sports activities and academic achievement (Jafari et al., 2019). Student-athletes need to develop effective time management skills to divide their time between studies, sports practice, and personal needs (Cosh & Tully, 2014). Student-athletes should create a structured daily or weekly schedule to ensure all responsibilities are met. They can use the time between practices or matches to read, do assignments, or absorb study material, bringing a book or laptop during travel or rest time (Turick et al., 2021). Apart from having achievement motivation and good study habits, student-athletes are required to have self-discipline (Grace et al., 2019).

Self-discipline plays a key role in maintaining a balance between commitment to sport and academic achievement (Medina et al., 2020). The ability to manage time effectively, maintain focus on academic tasks, and remain consistent in maintaining physical and mental health are determining factors in the success of student-athletes at the high school level (Altun et al., 2021). Self-discipline starts with the ability to set priorities well. Student-athletes need to understand that both academic achievements and sporting achievements have important values, and they must be able to determine the order of importance according to their needs and responsibilities. Self-discipline involves effective communication with coaches, teachers, and teammates. Student-athletes must be able to communicate their needs, explain time constraints, and ask for help if needed. A disciplined student-athlete must be able to self-reflect regularly. This involves reviewing academic and sporting performance. Student-athletes with self-discipline can face the unique challenges of maintaining a balance between sports and academic performance.

Good academic achievement often reflects the level of balance that student-athletes successfully maintain (Yukhymenko-Lescroart, 2018). Therefore, looking at their academic achievements can provide an idea of the extent to which they have succeeded in integrating sports into their educational life. A student-athlete's academic performance refers to his or her academic achievements in an educational environment, which involves several evaluation indicators but is not limited to achievement of grades, participation in classes, and involvement in academic activities (Grimit, 2014). This academic achievement is a specific and comprehensive picture of a student-athlete's ability and dedication to achieving their educational goals. An academically successful student-athlete demonstrates consistency in class attendance and active participation in discussions. Good attendance reflects their commitment to education, while active participation shows a desire to understand and engage in the learning material. A student-athletes academic performance is reflected in the achievement of strong grades. This includes their ability to achieve the academic standards set by educational institutions. They must demonstrate the ability to master course material and apply it in exams and assignments.

Learning barriers can present an extra challenge for student-athletes at the high school level. Time constraints, stress, and pressure associated with sports competitions can complicate their learning efforts (Ferreira Silva et al., 2021) Understanding the barriers experienced by student-athletes can help schools and coaches identify ways to provide more effective support (Banwell & Kerr, 2016). Barriers to the learning process for student-athletes can be complex and require a deep understanding of the multiple demands they face. Student-athletes are often faced with busy schedules, with time-consuming training, competitions, and travel. This can result in limited time for studies, making it difficult for them to balance academic work and sporting commitments. Intense competition in the world of sports can create additional pressure for student-athletes. Focusing on high sporting achievements may distract them from academic tasks, affecting concentration and quality of learning. Maintaining a balance between academic work and sports training is a challenge in itself. Student-athletes can have difficulty adjusting to changing schedules and managing their time efficiently.

Several previous studies have studied student-athletes in Bengkulu City, such as research from (Pujianto et al., 2022) which studied the mental toughness of student-athletes in Bengkulu City. Furthermore, (Pujianto et al., 2023) studied the emotional intelligence of student-athletes at the university level. However, specific studies regarding the psychological and academic conditions of student-athletes have not been widely discussed. Student-athletes are a valuable asset for the continued achievement of a nation. Therefore, it is necessary to carry out a comprehensive analysis of the characteristics of student-athletes in Bengkulu City by examining achievement motivation, study habits, self-discipline, academic support, and academic performance.

Based on the background description, the formulation of this research is: 1) What are the characteristics of high school student-athletes in Bengkulu City in terms of their level of achievement motivation, study habits, self-discipline, academic support, and academic performance? 2) Are there differences in the characteristics of male and female student-athletes? 3) Are there differences in the characteristics of student-athletes from individual and team sports?

The main goal of this research is to provide a comprehensive picture of the context, challenges, and

complexities of the lives of student-athletes at the middle school and high school levels. By understanding factors such as motivation, study habits, self-discipline, academic achievement, and learning support, it is hoped that this research can make a significant contribution to establishing better sports education and development for middle school and high school student-athletes in Bengkulu City.

Materials and methods

Participants

Research participants were student-athletes in Bengkulu City who were studying at the junior high school and high school levels. The total number of participants involved was 402 student-athletes.

Table 1. Characteristics of the student-athletes.

Sex	Frequency
Male	256
Female	146
Total	402
Level of Education	**Frequency**
Junior High School	107
Senior High School	295
Total	402
Type of sports	**Frequency**
Pencak Silat	65
Wrestling	1
Tae Kwon Do	34
Karate	50
Boxing	2
Volleyball	79
Basketball	44
Futsal	77
Gateball	2
Tennis	1
Table Tenis	1
Football	29
Badminton	10
Swimming	5
Bodybuilding	1
Athletic	1
Total	402

Research Design

This research is a quantitative descriptive study using a survey approach on middle school and high school student-athletes. The research instrument used for data collection was a questionnaire prepared and developed by the research team. The questionnaire consists of several indicators including achievement motivation, study habits, self-discipline, and learning support. The total items from the questionnaire used were 36 items. The Likert scale is used for choices, namely: strongly disagree-strongly agree. The questionnaire was field-tested on 322 student-athletes to determine the validity and reliability values of the instrument. From the results of the analysis using SPSS version 22, it is known that the instrument is concluded to be valid with a sig value <0.05, and the reliability of the instrument based on Cronbach's alpha is 0.83.

Research procedure

This research was carried out in several stages which are summarized in the research procedure, including explaining the purpose of the research and getting approval from the athletes regarding the data needed in the research, research data was collected through an instrument in the form of a questionnaire, data collection was taken manually by meeting directly between the researcher and the athlete. After the data is collected, data tabulation is carried out by taking the research data filled in completely by the athlete. The next step is to carry out analysis and present the research results.

Statistical Analysis

To determine the level of achievement motivation, study habits, self-discipline, and academic support, researchers developed criteria using the ideal mean and ideal

Table 3. Formula of Categories

Interval	Frequency
> (Mi + 1.8 SD) – (Mi + 3 SD)	Very High
> (Mi + 0.6 SD) – (Mi + 1.8 SD)	High
> (Mi – 0.6SD) – (Mi + 0.6 SD)	Moderate
> (Mi – 1.8 SD) – (Mi – 0.6SD)	Low
(Mi – 3SD) – (Mi – 1.8 SD)	Very Low

Mi = (ST+SR)/2; SD = (ST–SR)/6; Mi = Mean Ideal, ST = Maximum Score, SR = Minimum Score, SD = Standard Deviation

Table 2. Research instrument grid

Indicators	Description	Positive items	Negative items
Motivation	Motivation is a complex psychological construct that plays an important role in encouraging individuals to set and pursue goals, overcome challenges, and strive for success.	1, 2, 3, 4, 6, 7, 8, 9	5, 10
Study habit	Student-athlete study habits represent a unique intersection between academic and athletic demands.	11, 13, 14, 16, 17, 18, 19, 20	12, 15
Self-discipline	Self-discipline is an important attribute for success in both academics and athletics and student-athletes, it is even more important because of the dual demands they face.	21, 22, 23, 24, 26, 27, 28, 29, 30	25
Academic support	Academic support for student-athletes is critical to ensuring their success both in the classroom and on the field.	32, 33, 35, 36	31, 34

standard deviation formula which can be seen in Table 3. An Independent sample t-test assisted by SPSS variant 22 software was used to analyze data regarding differences between student-athletes in terms of gender and analyze data regarding differences between student-athletes in terms of type of sport.

Results

Describes the characteristics of secondary school student-athletes in Bengkulu City, shown through the indicators presented in the tables below.

Table 4. The result of Motivation

Interval	Category	Frequency	Percentage
44-51	Very High	108	26.87
35-43	High	272	67.66
27-34	Moderate	21	5.22
18-26	Low	1	0.25
9-17	Very Low	0	0

Based on Table 4, it is known that the data categorizes athletes into different achievement motivation intervals. The highest frequency is in the "35-43" interval which is categorized as "High" with 272 incidents or representing 67.66% of the total data. The second highest frequency was in the "44-51" interval with the "Very High" category with 108 incidents or covering 26.87% of the data. The majority of athletes fall into the "High" and "Very High" achievement motivation categories, namely 94.53% of the total data. The "Medium" achievement motivation category has a relatively lower frequency (5.22%), while the "Low" and "Very Low" categories have negligible frequencies (0.25% and 0% respectively). The high frequency in the "High" and "Very High" categories indicates that the majority of athletes in the data set have strong achievement motivation. Athletes with high achievement motivation are often more enthusiastic, goal-oriented, and persistent in their pursuit of success, which can positively influence their athletic performance. The low incidence in the "Low" and "Very Low" categories indicates that very few athletes in the data set reported lower levels of achievement motivation.

Table 5. The result of the study habit

Interval	Category	Frequency	Percentage
44-51	Very High	53	13.18
35-43	High	282	70.15
27-34	Moderate	65	16.17
18-26	Low	2	0.5
9-17	Very Low	0	0

The results of the research on the second indicator, namely study habits, are displayed in Table 5. From Table 5 it is known that the data is categorized into different intervals based on several criteria. The highest frequency was found in the "35-43" interval which was categorized as "high" with 282 athletes or representing 70.15% of the total data. The second highest frequency was in the "27-34" interval, categorized as "medium", with 65 incidents, which was 16.17% of the data. The majority of data falls into the "high" and "medium" categories, namely 86.32% of the total data. The "very high" category has a lower frequency (13.18%), while the "low" category has a very small frequency (0.5%). This means that student-athletes in the city of Bengkulu have good study habits.

Table 6. The result of self-discipline

Interval	Category	Frequency	Percentage
44-51	Very High	101	25.12
35-43	High	276	68.66
27-34	Moderate	23	5.72
18-26	Low	2	0.50
9-17	Very Low	0	0.00

The results of research on athlete self-discipline are shown in Table 6. From Table 6, information is obtained that the data categorizes athletes into different self-discipline intervals. The highest frequency is in the "35-43" interval which is categorized as "High" with 276 incidents or representing 68.66% of the total data. The second highest frequency is in the "44-51" interval which is categorized as "Very High" with 101 events which is 25.12% of the data. The majority of athletes fall into the "High" and "Very High" self-discipline categories, which is 93.78% of the total data. The "Medium" self-discipline category has a relatively lower frequency (5.72%), while the "Low" category has a relatively small frequency (0.50%). The high frequency in the "High" and "Very High" categories shows that the majority of athletes in the data set show strong self-discipline.

Table 7. The result of academic support

Interval	Category	Frequency	Percentage
26-30	Very high	73	18.15
21-25	High	139	34.58
17-20	Moderate	125	31.10
12-16	Low	64	15.92
6-11	Very low	1	0.25

The next indicator is academic support which is displayed in table 7. This data categorizes student-athletes into different academic support intervals. The highest frequency is in the "21-25" interval which is categorized as "High" with 139 incidents or representing 34.58% of the total data. The second highest frequency is in the "26-30" interval which is categorized as "Very High" with 73 events which is 18.15% of the data. The majority of student-athletes fell into the "High" and "Very High" academic support categories, accounting for 52.73% of the total data. The "Medium" academic support category has a significant frequency (31.10%), while the "Low" and "Very Low" categories also have a significant frequency (15.92% and 0.25% respectively). The high frequency in the "High" and "Very High" categories indicates that the majority of student-athletes in the data set have access to effective academic support.

Table 8 shows that the intervals 85-100 and 80-84 show high frequencies (175 and 170 respectively). This suggests

that student-athletes, overall, perform well academically, with most athletes achieving scores in the higher range. Data shows that student-athletes successfully balance their academic responsibilities with their athletic commitments. This is especially visible at high frequencies in the top two scoring intervals.

Table 8. Academic Performa

Interval	Letter	Frequency
85-100	A	175
80-84	A-	170
75-79	B+	51
70-74	B	6
65-69	B-	0

Based on Table 9, it is known that the sample consisted of 256 male student-athletes and 146 female student-athletes. This indicates a greater representation of men in the data set. The average score for male student-athletes was 143.83 and for female student-athletes was 139.99. This shows that on average male student athletes have slightly higher performance scores than female student athletes. A higher standard deviation for men indicates a wider range of performance scores than for women.

Table 9. Group statistics on male and female athletes

Sex	N	Mean	Std. deviation	Std. Error Mean
Male	256	143.83	11.3777	0.711
Female	146	139.99	10.347	0.856

To determine the level of difference between the characteristics of male and female student-athletes, an independent sample t-test analysis was carried out. The results of the prerequisite test using Monte Carlo obtained a sig value of .05 > 0.05 so that the data was normally distributed. Furthermore, analysis using Levene statistics obtained a sig value of .369 so that the data was homogeneously distributed. The results of the independent sample t-test at a significance level of 0.05 show that there are significant differences between male and female athletes which are presented in Table 10.

Table 10. Independent sample t-test of male and female student-athletes

t	df	Sig.(2 tailed)	Description
3.367	400	0.001	Significant

From the research results shown in Table 10, it is known that this study consisted of 170 student-athletes from individual sports and 232 athletes from team sports. Based on the mean scores, it is known that student-athletes from team sports have slightly higher scores than student-athletes from individual sports. To prove whether or not there are differences between the two groups, an independent sample t-test was carried out which is shown in Table 11. The results of the independent sample t-test at a significance level of 0.05 show that there are no significant differences between student-athletes from individual sports and sports. team.

Table 11. Group statistics from individual sports and team sports

Sport	N	Mean	Std. deviation	Std. Error Mean
Individual	170	141.94	10.698	0.711
Team	232	142.80	11.488	0.856

To determine the level of difference between the characteristics of student-athletes from individual and team sports, an independent sample t-test analysis was carried out. The results of the prerequisite test using Monte Carlo obtained a sig value of .05 > 0.05 so that the data was normally distributed. Furthermore, analysis using Levene statistics obtained a sig value of .369 so that the data was homogeneously distributed. The results of the independent sample t-test at a significance level of 0.05 show that there are no significant differences between student-athletes from individual and team sports as presented in Table 12.

Table 12. Independent sample t-test from individual sports and team sports

t	df	Sig.(2 tailed)	Description
-0.769	400	0.442	No Significant

Discussion

This research aims to reveal the characteristics of student-athletes at the middle and high school levels in Bengkulu City. These characteristics consist of achievement motivation, study habits, self-discipline, academic support, and academic performance.

The research results show that student-athletes in Bengkulu City have achievement motivation in the high category. The high achievement motivation of student-athletes in Bengkulu City is demonstrated by their persistence in training, belief in becoming winners and having clear goals for their involvement in their chosen sport. The findings of this research are in line with previous studies that successful student-athletes are athletes who have high achievement motivation (Matmask & Ozrudi, 2019). Sports achievement motivation in student-athletes is a dynamic and diverse concept that includes drive, determination, and the desire to excel in sports (Colin J. Deal & Camiré, 2016). Achievement motivation is a force that encourages individuals to set goals, persevere through challenges, and continue to strive to achieve personal and team success (Sharma et al., 2018). Student athletes' achievement motivation is often triggered by a combination of internal and external factors (Stokowski et al., 2013). Internally, these individuals have a deep passion for their sport, finding intrinsic joy in the process of improvement and competition (Gardner et al., 2017). The journey of a student-athlete is full of challenges, including rigorous training schedules, demanding academic commitments, and the inevitable setbacks in sports. However, those who have high achievement motivation show resilience and a tenacious spirit (Akbar et al., 2023). They view setbacks as opportunities to grow, learn from failures, and use them as stepping stones to future success. Sports achievement motivation in student-athletes also contributes to team cohesion and collective success. A shared commitment to excellence fosters a sense of camaraderie and mutual support, creating

a positive and competitive team culture. This motivation not only improves the performance of individual athletes but also pushes the entire team to higher levels (Javed et al., 2020).

In the second indicator regarding study habits, junior and senior high school student-athletes in Bengkulu City show the high category. This is demonstrated through the athlete's ability to complete school assignments on time, actively participate in the learning process in class, and give the best effort in taking exams in academic classes. The study habits of student-athletes reflect a balancing act between the demands of academic life and a commitment to excellence in sports (Linnér et al., 2021). One key aspect of a student-athlete's study habits is careful time management (Coffey & Davis, 2019). Student-athletes must be able to manage a tight schedule of practices, competitions, and travel. The ability to prioritize tasks and maintain a disciplined approach to time management are characteristics of successful student-athletes (Hardin & Pate, 2013). The study habits of student-athletes also underscore their commitment to academic excellence (Huml et al., 2014). Despite the physical and mental demands of their sport, many student-athletes prioritize their education, considering it the foundation of their future outside of athletics. This commitment often translates into disciplined study sessions, seeking additional support when needed, and actively engaging in coursework to ensure a well-rounded academic experience. Additionally, the sense of discipline and perseverance developed through sports often carries over into the study habits of student-athletes. The resilience they show on the field translates into a determined academic approach. When faced with challenging coursework or tight deadlines, these individuals harness the same mental strength that drives them in sports, overcoming academic challenges with a focused and persistent mindset.

In the third indicator, namely self-discipline, student-athletes in Bengkulu City show that they have high self-discipline. This is demonstrated by student-athletes by arriving on time for practice and studying academically in class, being responsible as athletes and students. Self-discipline is a hallmark of student-athletes, manifesting in their ability to regulate behavior, prioritize tasks, and persevere in the pursuit of academic and athletic excellence (Claringbould et al., 2015). These qualities are important for dealing with the demanding schedules and high expectations that come with balancing rigorous training programs and academic responsibilities (Zulkifli & Rahmat, 2022). Student-athletes carefully plan their daily routines, allocating time for classes, training sessions, study periods, and rest (Macquet & Skalej, 2015). Through this careful planning, they establish a framework that allows them to manage their time and energy effectively, ensuring that neither their athletic activities nor their academic obligations are neglected (Nordito S Quimbo, 2023). The high demands faced by student-athletes often require sacrifice, and self-discipline plays an important role in making and sticking to these choices (Sanders et al., 2021). Whether it's choosing to stay focused during study sessions, maintaining a healthy diet, getting enough sleep, or not engaging in distractions, student-athletes demonstrate a high level of self-control in their daily lives. This discipline extends to areas beyond the immediate demands of their sport, contributing to their overall well-being and long-term success. Student-athletes demonstrate a sense of delayed gratification, realizing that the hard work and sacrifices they make now will contribute to future success (Strowd et al., 2022). This forward-thinking mindset allows them to resist short-term temptations or distractions, and remain committed to their long-term goals (Nichols et al., 2019). The journey in both academics and sports is marked by challenges, setbacks, and moments of difficulty (Sorkkila et al., 2019). Through self-discipline, student-athletes develop the mental fortitude to persevere in the face of obstacles. They view challenges not as insurmountable obstacles, but as opportunities to grow and develop and demonstrate resilience in their efforts to continue achieving excellence (Sullivan et al., 2023).

Another indicator that is part of this research is academic support. In this research, student-athletes received good academic support. This is shown by the support from teachers at school and parents at home. The results of this research are in line with various previous studies that reveal that successful learning athletes are those who receive academic support (Hazzaa et al., 2018). Academic support for student-athletes plays a critical role in ensuring their success both in the classroom and on the field (Lassiter & Campbell, 2023). One important aspect of academic support for student-athletes is the provision of dedicated academic advisors (Grandy et al., 2016). These advisors specialize in understanding the intricacies of athletic schedules, competitions, and training programs (Vaughn & Smith, 2018). They work closely with student-athletes to create personalized academic plans, assist them in selecting classes that align with their training commitments, and ensure they meet eligibility requirements to participate in sports. Tutoring services are often the cornerstone of academic support for student-athletes (Karakaya et al., 2015). Tutors work with student-athletes to clarify concepts, review coursework, and strengthen their understanding, fostering a supportive academic environment that complements their athletic activities (Kirby & Amason, 2021). Time management workshops are often offered to help student-athletes effectively balance their academic and athletic responsibilities (Colin Jeffery Deal & Camiré, 2016). This workshop provides strategies for managing schedules, setting priorities, and maximizing productivity. By instilling effective time management skills, academic support programs empower student-athletes to meet deadlines, attend classes, and engage in focused study sessions without sacrificing their athletic commitments. Flexible academic accommodations are often implemented to address the unpredictable nature of sports schedules (Condello et al., 2019). These accommodations ensure that academic progress is not hampered by the unique challenges of a dual-role lifestyle.

This research also revealed differences in the characteristics of male and female athletes in terms of motivation, study habits, discipline, academic support, and academic performance. The results of the analysis show that the average score of male athletes is greater than that of female athletes. From the results of statistical analysis with a significance level of 0.05, it is known that there are significant differences. These differences can be discussed from each indicator. The results of this research are relevant to previous research which revealed that there are differences in the motivation of male and female athletes (Moradi et al., 2020). Male athletes have higher motivation (Ong, 2019). These differences can be shaped by a variety of factors, including societal expectations,

cultural norms, and individual experiences (Navarro & Malvaso, 2015). Societal expectations place a higher value on male athletic traits causing male student-athletes to be motivated by the desire to gain recognition, respect, and social status. Meanwhile, female student-athletes are motivated to challenge stereotypes, break down barriers, and promote gender equality. Male student athletes tend to have extrinsic motivations such as a desire for scholarships, awards, or professional opportunities. Meanwhile, female student-athletes are intrinsically motivated, finding joy and satisfaction in the process of improvement, personal growth, and love for the sport itself. Judging from study habits, male student-athletes tend to postpone work more often, adapt easily to various environmental conditions, and use assertive and competitive study techniques. Meanwhile, female athletes are more organized in carrying out academic and sports tasks and need a comfortable environment to adapt, and use cooperative learning and discussion techniques. Judging from the discipline, it is known that male student-athletes set goals for long-term goals, are susceptible to time management, and show resilience through the ability to rise from adversity. Meanwhile, female athletes set goals by combining personal and team goals, are organized in time management and show resilience through emotional intelligence. Judging from academic support and academic performance, male student-athletes tend to experience obstacles in balancing academic demands and sports demands. A collaborative academic environment or team-related academic challenges may be very effective for some male student-athletes. Meanwhile, female athletes tend to be more adept at balancing academic demands and sporting demands, tending to seek help from friends, coaches, or mentors when facing academic challenges.

This research also revealed the differences in the characteristics of athletes from individual sports and team sports in terms of motivation, study habits, discipline, academic support, and academic performance. The results of the analysis show that there is no significant difference in the average scores of athletes from individual sports and team sports. From the results of statistical analysis with a significance level of 0.05, it is known that there are no significant differences. Both individual student-athletes and teams often share a passion for their sport (Jakobsen, 2018). Love of the game can be a powerful motivator to put in the effort and time necessary to become the best. Individual and team student-athletes often have a strong work ethic. They understand the correlation between hard work and success, and commitment to putting in the necessary effort is the common thread of motivation. Both individual student-athletes and teams need strong time management skills. Balancing training sessions, competitions and academic commitments requires effective planning to ensure they allocate sufficient time to both areas of their lives. Consistency in study routines is critical to academic success for individual athletes and teams. Both types of athletes must be adept at utilizing available resources, such as libraries, online materials, and academic support services.

Conclusions

Based on the research results conducted in Bengkulu City, it can be concluded that student-athletes in the region generally exhibit high levels of achievement motivation, study habits, self-discipline, academic support, and academic performance. This suggests a positive and conducive environment for the academic development of student-athletes. Furthermore, a significant difference was observed between male and female student-athletes, indicating that gender plays a role in influencing certain aspects of their academic experiences. The differences could be attributed to various factors such as societal expectations, individual preferences, or cultural influences. However, no significant differences were found between student-athletes engaged in individual sports and those participating in team sports. This implies that the type of sport, whether individual or team-based, does not have a statistically significant impact on the measured academic factors among the student-athletes in Bengkulu City. In summary, the findings suggest a need for tailored support and interventions that consider gender-specific factors for optimizing the academic experiences of student-athletes. Additionally, the lack of significant differences between individual and team sports indicates that both types of sports may contribute equally to the positive academic outcomes observed in the student-athlete population in Bengkulu City.

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Conflict of interest

The authors declare there is no conflict of interest.

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Учні-спортсмени старшої школи: їх мотивація, навчальні звички, самодисципліна, академічна підтримка та академічна успішність

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 10 с., 12 табл., 56 джерел.

Мета дослідження. Учням-спортсменам нелегко балансувати між функціями спортсмена та учня в школі. Чимало з них мають перешкоди у балансуванні обох функцій. Метою даного дослідження є визначення характеристики показників учнів-спортсменів середніх шкіл у місті Бенгкулу. Основними задачами дослідження є опис рівня мотивації досягнення, навчальних звичок, самодисципліни, академічної підтримки та академічної успішності.

Матеріали та методи. Це кількісне описове дослідження з використанням методу анкетування, в якому взяли участь 402 учні-спортсмени на рівні середньої та старшої школи. Учні-спортсмени представляють 16 видів спорту. Середній вік учнів-спортсменів становить 15,9 років. Інструментом, що використовувався в дослідженні, був опитувальник, складений з 36 пунктів тверджень. Для аналізу даних щодо рівня категорії кожного показника використовувалися формули оптимального середнього та стандартного відхилення, а для визначення відмінностей даних між учнями-спортсменами залежно від статі та виду спорту застосовувався t-критерій для незалежних вибірок.

Результати. Результати дослідження показують, що учні-спортсмени міста Бенгкулу мають високий рівень мотивації досягнення, навичок навчання, самодисципліни, академічної підтримки та академічної успішності. Існує значна різниця у показниках серед учнів-спортсменів чоловічої та жіночої статі (sig 0,001 < 0,005). Значущих відмінностей у показниках серед учнів-спортсменів з індивідуальних та командних видів спорту не спостерігалося (0,442 > 0,005).

Висновки. Учні-спортсмени молодших та старших класів середньої школи навчання мають позитивну характеристику показників, є значущі відмінності між спортсменами чоловічої та жіночої статі, а також відсутні значущі відмінності між спортсменами індивідуальних та командних видів спорту.

Ключові слова: учні-спортсмени, мотивація, звички, дисципліна, академічний.

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Improvement of Motor Skills and Motivation to Learn Physical Education Through the Use of Traditional Games

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Abstract

Study purpose. This study aims to investigate motor skills and motivation to learn physical education through traditional games.

Materials and methods. The study was conducted using an experimental method and involved 60 students from primary schools in Purwodadi District, Grobogan Regency, Indonesia. Data were collected by measuring motor skills and learning motivation through affective, cognitive and psychomotor tests that were examined for validity and reliability. In addition, students' character was also measured through observational tests of students' basic movement skills. The measurement of basic movement skills was carried out before and after the intervention, which lasted for 8 sessions over one month. Data analysis was carried out using the Anova technique, reinforced by regression of research results using SPSS 22 software.

Results. The results showed that the traditional game approach had a significant effect on increasing students' motivation to learn physical education. The traditional games approach also contributed positively to students' learning outcomes. Through hands-on experience in these traditional games, students can develop motor skills, coordination, speed, strength, as well as cognitive aspects such as strategy, spatial intelligence and situation analysis.

Conclusions. By participating in traditional games, students can understand and respect cultural heritage and broaden their horizons about cultural diversity. Suggestions for future investigations include extending the research and development activities by including a larger sample, which may provide greater statistical power to support research findings in the area of traditional games.

Keywords: motor skills, motivation, physical education, traditional games, improved.

Introduction

Physical education is one of the essential aspects of education systems worldwide (Kern & Armstrong, 2022). In international physical education policy, many countries prioritize the development of curricula that cover physical education from elementary school to college level (Hosker et al., 2019). In addition, adequate sports facilities, qualified sports coaches, and programs that teach essential values are also part of the policy. Good physical education can benefit students by improving physical and mental health, developing social abilities and team skills, and improving academic achievement (Jackson et al., 2022). Therefore, countries worldwide must prioritize physical education in their education systems to create healthier and more physically and socially active societies (Chekroud et al., 2018). Motor skills and physical education learning motivation align with the mentioned International Physical Education Policy (Aliriad et al., 2023). Motor skills are a person's ability to perform physical movements in a precise and coordinated manner (Aliriad, 2023). Developing motor

skills through practice and playing sports is essential to help students acquire expertise in performing physical activities correctly and effectively.

Physical education study motivation refers to a student's interest and passion for learning and participating in sports and fitness activities. International Physical Education Policy includes developing programs that motivate students to participate in sports and fitness activities, such as teaching important values, ensuring safety and health in every move, and providing opportunities to participate in international sports competitions (Limbu et al., 2017).

Motor skills and motivation to learn physical education are essential in improving the overall quality of physical education (Chen, 2017). By developing motor skills and motivation to learn physical education, students can obtain more significant benefits, such as improving health and fitness, social and team abilities, and academic achievement. Therefore, it is essential for education systems around the world to pay attention to the development of motor skills and motivation for learning physical education in their physical education policies (Adi et al., 2023).

Another study conducted on early childhood in Canada found that physical education programs explicitly designed to improve motor skills could significantly improve students' motor skills (Kjær, 2019; Rawat & Bangari, 2019). The Program consists of various physical activities performed under the supervision of trained educators and with sufficient repetition and variety to strengthen the student's motor skills (Balaban, 2018). The results of this study show that physical education programs that focus on developing motor skills can significantly improve students' motor skills and provide other benefits, such as increasing self-confidence and self-confidence in early (Chou et al., 2022; Valentini et al., 2016).

Traditional games have many vital values, such as cooperation, discipline, patience, healthy competition, and respect for colleagues and opponents (Leddington Wright et al., 2015; Sulistyaningtyas & Fauziah, 2019). One example of a conventional game containing these values is "gobak sodor" or "gobak jalan". In this game, the players work together to knock the opponent off the line, which is the limit of the game. In the process, they must have discipline, patience in waiting for their turn, and cooperation to bring down opponents together. There is healthy competition that spurs the spirit to be the best but still respects colleagues and opponents to play by not cheating or harming. By playing traditional games such as "gobak sodor", children can develop these critical values early on and apply them in everyday life (Kashyap, 2017).

In a "sack race" or "tug of war" game, the players must work together and support each other to achieve a common goal, such as capturing a flag or pulling a rope (Van Capelle et al., 2017). In addition, they must also be responsible for their respective duties and roles in the team. Activities like this can strengthen the cultural values of cooperation and responsibility in children and enhance the sense of solidarity and togetherness in the group (Ahmed et al., 2021; Pang & Fong, 2009). It can also help build children's character and independence to become resilient and responsible individuals (Schembri et al., 2019).

Physical education teaches personal and Social Responsibility and aims to develop responsibility (Brock & Hastie, 2017). The Sports Union to Promote Education and Recreation (SUPER) program is designed to build life skills through sports play activities. Strachan, Mac Donald, and Cote (2016) argue that connect and respect sports (SCORE) are physical activities and education designed to develop students' attitudes and behaviours.

This study aimed to obtain data and information on the effectiveness of traditional games in improving motor skills and student learning motivation in physical education. In addition, this study also aims to re-promote conventional games as an effective means of enriching physical education activities in schools. Thus, this study is expected to provide significant benefits for teachers and students in improving the quality of physical education in schools. Therefore, the study's results can help overcome gaps and provide verified solutions to enhance motor skills and motivation to study physical education.

Materials and methods

Study participants

The study involved 60 male students from a local elementary school in Kecamatan Purwodadi, Kabupaten Grobogan, Indonesia. The participants were not randomly assigned, and there was no control group in this experimental research design with a one-group pretest and posttest design. The average height of the participants was 139.98 cm (SD = 5.52), and their average weight was 35.33 kg (SD = 6.78). The average age of study participants was 11.6 years and a standard deviation of 0.89.

Study organization

This study utilises an experimental method with a design consisting of one Pretest and Posttest group, without a control group and random subject placement. Data collection involves assessment instruments for psychomotor, affective, and cognitive aspects in physical education learning. Validation of the instrument using Principal Component Analysis (PCA) showed a strong correlation (0.891) between traditional and motivational game variables. Reliability analysis with Cronbach's Alpha yielded a value of 0.730, indicating good consistency. The study involved 60 male elementary school students in Purwodadi Sub-District, Grobogan Regency, Indonesia, with an average height and weight reflecting the age range of 10-12 years. The study intervention comprised eight sessions over one month, during which traditional games such as Gobak Sodor, sack race, and tug of war were employed.

Statistical analysis.

Statistical analysis is a mathematical method used to investigate and present relevant information from a study or experiment. It involves several approaches, including hypothesis testing, regression and correlation, analysis of variance (ANOVA), chi-squared analysis, and descriptive statistics. Hypothesis testing is used to determine the validity of a statement based on existing data samples. Regression and correlation are statistical methods used to analyse the relationships between variables and make predictions based on patterns of these relationships. ANOVA is a statistical

test used to measure the significant difference between the means of more than two groups, while chi-squared analysis is useful for assessing the relationship between categorical variables. Descriptive statistics, such as mean, median, mode, and standard deviation, are used to summarise and present data more simply. Selecting the appropriate statistical method depends on the data type, research objectives, and the questions to be answered. Statistical analysis is a crucial tool for comprehending data patterns, identifying trends, and drawing dependable conclusions from available data samples.

Measurement

The success of research is primarily determined by the research instruments used. Because the data obtained to answer a study was obtained through research instruments. Research instruments can be defined as tools or facilities used to collect data so that it is more accurate and systematic. To measure the effect of the traditional game approach on improving motivation and learning outcomes of Health Care Providers, some of the instruments used are: 1) study motivation questionnaire: to measure students' motivation levels before and after using the traditional game approach (Amrullah et al., 2023). 2) Physical education learning outcomes test: to measure the level of student learning outcomes before and after using a traditional game approach. The instrument will be used to collect data and measure the effect of traditional game approaches on improving motivation and learning outcomes.

Results

The researchers have designed an assessment sheet validated using the Principal Component Analysis (PCA) method. The results showed that traditional games and

Table 1. Student Motivation Questionnaire

Question	1	2	3	4	5
How often do you feel drawn to the lessons of Physical education?					
How often do you feel attracted to participate in traditional games during Orchestra lessons?					
Do you feel more interested in learning Physical education using a traditional game approach?					
How often do you feel more motivated to learn Orchestra lessons when using a traditional playing approach?					
Do you find using a traditional game approach easier to understand orchestral Physical education material?					
How often do you feel more comfortable and excited when learning Physical education with a traditional game approach?					
Do you feel more interested in learning Physical education after using the traditional game approach?					
How often do you feel more motivated to practice Orchestra after using a traditional approach to the game?					
Do you feel your learning outcomes have improved after using the traditional game approach?					
How important do you consider the traditional game approach in improving motivation and learning outcomes?					

Table 2. Assessment sheet for Cognitive, Affective and psychomotor aspects

Cognitive:	1	2	3	4	5
Ability to understand the concept of Physical Education broadly and deeply					
Ability to apply concepts in real situations					
Problem-solving and problem-solving skills in situations related to Physical Education					
Ability to process information and make connections between physical Education concepts					
Affective:	**1**	**2**	**3**	**4**	**5**
Level of interest and enthusiasm when studying Physical Education					
Ability to concentrate and focus while studying					
Level of confidence and satisfaction when applying Physical Education concepts					
Level of care and responsibility for Physical Education materials					
An attitude of respect and respect for the human rights that everyone has					
Ability to listen, share ideas, and take action that is good for the team as a whole					
A positive attitude toward one's ability to perform tasks and achieve goals					
Psychomotor	**1**	**2**	**3**	**4**	**5**
Ability to apply concepts and techniques in practical Physical Education situations					
Demonstrated ability to demonstrate skills and proficiency in physical Education practice situations					
Ability to adapt and collaborate in situations of Physical Education Practice					
Ability to demonstrate creativity and innovation in physical Education practice situations					

motivation variables have a high correlation coefficient of 0.891, so the two variables can be used in factor analysis. Reliability analysis was performed using Cronbach's Alpha. The results showed that the instruments used to measure the two variables have a good level of consistency, with a reliability value of 0.730. Thus, the results of validity and reliability of this study can be considered valid and reliable. The number of samples in this study consisted of 60 students. This study has descriptive data on three variables: traditional games, motivation, and learning outcomes. The number of samples used was as many as 60 respondents. Traditional game variables have a range of values between 30.00 to 49.00, with an average score of 42.7000 and a standard deviation of 5.04656. Meanwhile, the motivation variable has a range of values between 24.00 to 50.00, with an average motivation score of 44.5333 and a standard deviation of 5.31537. In the variable learning outcomes, discounts range between 37.50 to 46.00, with an average score of 42.9167 learning outcomes and a standard deviation of 2.12764. All data obtained from 60 respondents were classified as valid (listwise) without missing or incomplete data. Thus, this descriptive data provides an overview of the variation of scores in traditional games, motivation, and learning outcomes in the study sample. The data can be seen in Table 3. Descriptive Statistics.

Table 3. Descriptive Statistics

Variable	N	Mean	Std. Deviation	Min	Max
Traditional games	60	42.7000	5.04656	30.00	49.00
Motivation	60	44.5333	5.31537	24.00	50.00
Learning outcomes	60	42.9167	2.12764	37.50	46.00
Valid N (listwise)	60				

Effect of traditional game approach on student motivation. In this Anova analysis, one model is reviewed, namely the model with predictor variables "traditional games" and target variables "motivation". The analysis showed that the model gives a sum of squares (sum of squares) of 481,512 with a degree of freedom (df) of 1. The Mean square of the model is 481,512. The value of F (F-ratio) was obtained by 23,559, with significance (Sig.) as big .000a (less than 0.05). The results of the ANOVA test showed a significant influence between the predictor variable "traditional games" and the target variable "motivation". The predictor variable can explain several variations in the target variable. In this model, constants are also included as predictors.

Table 4. Anova test of traditional games on student motivation

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	481.512	1	481.512	23.559	0.000[a]
	Residual	1185.421	58	20.438		
	Total	1666.933	59			

a. Predictors: (Constant), Traditional games

b. Dependent Variable: Motivation

The total sum of squares is 1666,933, with 59 degrees of freedom. Thus, based on this Anova analysis, a model incorporating the "traditional game" variable can significantly influence the "motivation" variable. In this regression model, there are two variables, namely "traditional games" and "motivation". The coefficients obtained from this regression analysis are constant (Constant): the coefficient value of 20,361 with a standard error of 5,014. The value of the t-ratio obtained is 4.061 with a significance of .000. Traditional games: the value of the coefficient is 0.566 with a standard error of 0.117. The value of the t-ratio obtained is 4.854 with a significance of .000. The standard coefficient for this variable is 0.537. In the context of the dependent variable "motivation", the results of the analysis show that there is a significant influence between the variables "traditional games" and "motivation". The value of the positive coefficient on the variable "traditional game" indicates that the higher the score of "traditional game", it will tend to increase the score of "motivation". The significance obtained suggests that this relationship did not happen by chance. Thus, the "traditional game" variable significantly contributes to predicting "motivation" in this model.

Table 5. Effect of traditional games on student motivation

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	20.361	5.014		4.061	0.000
	Traditional games	0.566	0.117	0.537	4.854	0.000

Dependent Variable: Motivation

In Table 6, an ANOVA test was conducted to see the effect of traditional game approaches on student learning outcomes. The results showed that the regression model provides a sum of squares (sum of squares) of 41,928 with degrees of freedom (df) of 1. The Mean square of the model is 41,928. The value of F (F-ratio) obtained is 10,801, with significance (Sig.) as big .002[a] (less than 0.05). This shows a significant influence between traditional game approaches and student learning outcomes. The total sum of squares is 267,083, with 59 degrees of freedom. In Table 7, coefficients are obtained from regression analysis to see the effect of traditional games on student learning outcomes.

Table 6. Anova test of traditional game approach to learning outcomes

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	41.928	1	41.928	10.801	0.002[a]
	Residual	225.155	58	3.882		
	Total	267.083	59			

a. Predictors: (Constant), Traditional games

b. Dependent Variable: Learning outcomes

The nonstandard constant (constant) coefficient is 35,784, with a standard error of 2,185. The value of the t-ratio obtained is 16.375 with a significance of .000. For the variable "Traditional Games" (traditional games), the value

Table 7. Effects of traditional games on student learning outcomes

Unstandardized Coefficients		Standardized Coefficients	t	Sig.
B	Std. Error	Beta		
35.784	2.185		16.375	0.000
0.167	0.051	0.396	3.286	0.002

a. Dependent Variable: Learning outcomes

of the coefficient is 0.167 with a standard error of 0.051. The value of the t-ratio obtained is 3.286, with a significance of .002. The standard coefficient (beta) for this variable is 0.396. In the context of the dependent variable "learning outcomes", the analysis results show a significant influence between traditional game approaches and student learning outcomes. The positive coefficient on the "traditional game" variable indicates that the higher the traditional game approach, will improve student learning outcomes. The significance obtained suggests that this relationship did not happen by chance. Thus, based on Table 6 and Table 7, the traditional game approach significantly influences student learning outcomes.

Table 8, 9 analyses the interaction between traditional games and student motivation to the dependent variable "motivation". The results of the study showed that there is a significant influence on these interactions. Type III Sum of Squares for the exchange is 823,313 with a degree of freedom (df) of 15. The Mean Square is 54,888. The F-ratio obtained is 2.863, with significance (Sig.) as oversized 0.003. This shows that the interaction between traditional games and student motivation significantly affects motivational variables. The total sum of squares is 120660,000, with 60 degrees of freedom. Table 8 analyses the interaction between traditional games and student learning outcomes against the dependent variable "learning outcomes".

Table 8. Interaction of traditional games on student motivation

Dependent Variable: Motivation					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	823.313a	15	54.888	2.863	0.003
Intercept	59223.024	1	59223.024	3.089E3	0.000
VAR00001	823.313	15	54.888	2.863	0.003
Error	843.620	44	19.173		
Total	120660.000	60			
Corrected Total	1666.933	59			

R Squared = 0.494 (Adjusted R Squared = 0.321)

The results of the analysis showed that there is a significant influence on these interactions. Type III Sum of Squares for the exchange is 139,495 with a degree of freedom (df) of 15. The Mean Square obtained is 9,300. The value of the F-ratio received is 3.207, with significance (Sig.) as oversized .001. This shows that the interaction between traditional games and student learning outcomes significantly influences learning outcome variables. The total

Table 9. Interaction of traditional games on student learning outcomes

Dependent Variable: Learning outcomes					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	139.495[a]	15	9.300	3.207	0.001
Intercept	55961.750	1	55961.750	1.930E4	0.000
VAR00001	139.495	15	9.300	3.207	0.001
Error	127.588	44	2.900		
Total	110777.500	60			
Corrected Total	267.083	59			

a. R Squared = 0.522 (Adjusted R Squared = 0.359)

sum of squares is 110,777,500, with 60 degrees of freedom. In both tables, the R-squared value indicates how much variability in the dependent variable can be described by the model used. The R-squared obtained is .494 for student motivation and .522 for student learning outcomes. Adjusted R-squared provides a revised estimate for the complexity of the model, and a value is obtained of .321 for student motivation and .359 for student learning outcomes. Based on the results of the analysis in Table 6 and Table 7, there is a significant interaction between traditional games with student motivation and student motivation and student learning outcomes.

Discussion

This study aims to investigate the influence of traditional games on student motivation and learning outcomes (Wang et al., 2021). The analysis showed exciting findings regarding the variables' validity, reliability, and impact. The validity and reliability of assessment instruments become essential in research. The number of samples in this study is as many as 60 students. Descriptive Data showed score variation in traditional games, motivation, and learning outcomes in the study sample. The average score for conventional games is 42.7000 with a standard deviation of 5.04656, the average score for a reason is 44.5333 with a standard deviation of 5.31537, and the average score for learning outcomes is 42.9167 with a standard deviation of 2.12764. All data obtained from 60 respondents were classified as valid with complete data. The effect of traditional games on student motivation and learning outcomes was tested using ANOVA and regression analysis. The results of the ANOVA analysis showed a significant influence between traditional games and student motivation, as well as between conventional games and student learning outcomes. Regression analysis showed a significant effect between classic games and student motivation and traditional games and student learning outcomes. Regression coefficients showed that the higher the score of conventional games, it will tend to improve motivation scores and student learning outcomes.

Furthermore, the interaction between traditional games and student motivation to student motivation and between conventional games and student learning outcomes is analyzed (Peebles et al., 2023). The analysis showed a significant interaction between traditional games and student motivation to student motivation and learning

outcomes (Peng et al., 2023). This indicates that the level of student motivation can influence the influence of traditional games on student motivation and learning outcomes (Hayati et al., 2017). The analysis showed a significant effect between traditional and classic games on student motivation and learning outcomes. This shows the importance of using traditional games in improving student motivation and learning outcomes (Pappous & Hayday, 2016).

The increased involvement and activity of students in the learning process can explain the influence of traditional games on student motivation (Pan et al., 2019). Classic games can provide a fun learning experience, engage social interaction, and increase students' intrinsic motivation (Martínez-Santos et al., 2020). The higher the standard game score, the higher the student's learning motivation (Hartanto et al., 2021). Several factors can explain the influence of traditional games on student learning outcomes. First, classic games can improve students' understanding of concepts and skills practically and interactively (Bakhtiar, 2014). Games allow students to apply the knowledge and skills learned in real and exciting situations (Y. Zhang, 2021). This can improve students' understanding and retention

of information. Second, traditional games can increase student learning motivation (Fadillah et al., 2021). With a fun and engaging learning experience, students are more motivated to participate in the learning process actively. High motivation can affect students' concentration and effort and contribute to better learning outcomes (Pezoa-Fuentes et al., 2023; F. Zhang et al., 2021). The analysis results also showed the interaction between traditional games and student motivation to student motivation, classic games and student learning outcomes to student learning outcomes (Luo et al., 2020). This indicates that the students' motivation level can influence conventional games' influence on student motivation and learning outcomes. Educators must pay attention to student motivation and ensure that traditional games are well integrated into teaching to maximize their benefits.

In conclusion, this study shows that traditional games significantly influence students' motivation and learning outcomes (Wallhead et al., 2014). These findings provide a solid basis for considering using conventional games as a practical approach to improving students' motivation and learning outcomes. Educators can utilize traditional games in learning to create a fun, interactive, and meaningful learning environment for students (Hong et al., 2022; Merino-Campos & del Castillo Fernndez, 2016). In addition, this study also shows the importance of paying attention to student motivation in designing effective learning strategies. In the context of essential motion learning, this study shows that using traditional games significantly affects student motivation and learning outcomes (Merino-Campos & del Castillo Fernndez, 2016). This can be related to learning basic movements because basic movements often involve motor and physical interaction between students.

Traditional games can be a practical approach to essential motion learning, providing a fun and interactive learning experience (Kurniawan et al., 2020). Students can actively move through the game, develop basic motor skills, and improve their body coordination (Kesumawati et al., 2021). This positive learning experience can motivate students to participate in essential movement learning and try new activities.In addition, traditional games can also enrich students' learning experience through social interaction and teamwork (O'Connor et al., 2022). In conventional games, students can learn about rules, strategies, and tactics that involve cooperation with teammates (Sembiring et al., 2020). It can develop students' social skills, such as communicating, cooperating, and building trust in basic motion (Jones et al., 2020). Furthermore, using traditional games in essential motion learning can also facilitate contextual learning. Through conventional games, students can experience movement in real situations relevant to their daily lives. This can help students associate learned moves with their use in everyday life, thereby strengthening their understanding of primary motion and improving the transfer of learning.

In this study, the influence of traditional games on student motivation and learning outcomes was also supported by statistical analysis that showed a significant correlation between standard game variables and student motivation, as well as traditional game variables and student learning outcomes (Kokstejn et al., 2019). These results indicate that essential motion learning utilizing classic games can increase students' motivation and positively contribute to learning outcomes. In virtual motion learning, educators can use traditional games as an exciting and effective strategy for teaching basic motion to students. By integrating conventional games into meaningful motion learning, students can be more engaged and motivated and have a significant learning experience.

This study can be synchronized with several relevant game theories, such as intrinsic motivation theory, the theory of learning through play (play-based learning), and the theory of Constructivism (Pambudi & Widiyanto, 2019). Intrinsic motivation theory: this study shows that using traditional games in essential motion learning can increase student motivation. This is to the idea of intrinsic motivation, which states that humans naturally want to seek satisfaction and pleasure in their activities (Finlay et al., 2022).

Traditional games provide students with a fun, challenging, and meaningful experience in essential motion learning (Wildani & Gazali, 2020). They feel engaged and motivated to actively participate in crucial motion learning because they enjoy the games and challenges provided. Theory of Learning Through Play (Play-Based Learning): This study supports learning through play, emphasizing the importance of games in learning. In traditional games, students learn through hands-on experience, social interaction, and exploration of their surroundings. They develop basic motor skills, social skills and understanding of concepts indirectly through play. In the context of essential motion learning, traditional games have become an effective tool to teach students basic motion in a fun and natural way. Constructivism theory: this study also supports the principles of Constructivism theory, which emphasizes that learning occurs through individuals' active construction of knowledge. In essential motion learning using traditional games, students build their understanding of movement through experience and interaction with their environment. They create mental representations about movement, test hypotheses, and refine their skills through in-game interactions. Through this process, students construct their knowledge of basic movements and develop their motor skills.

This study supports using traditional games in essential motion learning by linking them to intrinsic motivation theory, learning through play theory, and constructivism theory. In this context, classic games become practical tools to increase student motivation, facilitate learning through play experiences, and allow students to construct knowledge about basic movements actively.

Conclusions

The use of traditional games in essential motion learning has a positive impact. Classic games encourage students' intrinsic motivation, increasing engagement and active participation in education. In addition, traditional games also facilitate learning through play, where students learn naturally through interaction with their surroundings. The concepts of intrinsic motivation theory, learning through play, and Constructivism can be integrated to explain the importance of traditional games in essential motion learning. Thus, classic games are a relevant new theory in meaningful motion learning, as they provide a fun, challenging and effective approach for students to develop motor skills and understanding of concepts.

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Conflict of interest

The authors declare that they have no competition.

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Покращення рухових навичок та мотивації до занять фізичною культурою за допомогою традиційних ігор

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Мета дослідження. Це дослідження спрямоване на вивчення рухових навичок та мотивації до занять фізичною культурою за допомогою традиційних ігор.

Матеріали та методи. Дослідження було проведено з використанням експериментального методу за участю 60 учнів початкових шкіл району Пурводаді, регентство Гробоган, Індонезія. Дані були зібрані шляхом оцінки рухових навичок та навчальної мотивації за допомогою афективних, когнітивних та психомоторних тестів, які були досліджені на предмет валідності та достовірності. Крім того, за допомогою спостережень за основними руховими навичками учнів оцінювали також їхній характер. Оцінювання основних рухових навичок проводилося до і після інтервенції, яка тривала 8 сесій протягом одного місяця. Аналіз даних проводився із застосуванням методу дисперсійного аналізу (ANOVA), доповненого регресійним аналізом результатів дослідження за допомогою програмного забезпечення SPSS 22.

Результати. Результати дослідження показали, що традиційний ігровий підхід має значний вплив на підвищення мотивації учнів до занять фізичною культурою. Традиційний ігровий підхід також сприяв позитивному впливу на результати навчання учнів. Завдяки практичному досвіду в цих традиційних іграх, учні можуть розвивати рухові навички, координацію, швидкість, силу, а також когнітивні аспекти, такі як стратегія, просторове мислення та аналіз ситуації.

Висновки. Завдяки залученню до традиційних ігор учні мають можливість краще зрозуміти та поважати культурну спадщину, а також розширити свій кругозір щодо культурного розмаїття. Рекомендації для проведення подальших досліджень включають розширення науково-дослідницької роботи за рахунок включення більшої вибірки, що може забезпечити більшу статистичну потужність для підтримки результатів дослідження у сфері традиційних ігор.

Ключові слова: рухові навички, мотивація, фізична культура, традиційні ігри, вдосконалений.

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The Effect of a Six-Week Course of Surya Namaskar Practice on Back Flexibility and Lumbar Flexion in Male College Students

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Abstract

Study purpose. The strenuous Surya Namaskar exercise programme has gained considerable popularity among contemporary yoga practitioners. Its special combination of yogic breathing techniques, asanas (postures) and dharana (focused mind concentration) helps to improve flexibility. The aim of this study was to investigate the effectiveness of an original six-week course of Surya Namaskar on back flexibility and lumbar flexion in male college students.

Materials and methods. Thirty male college students aged between eighteen and twenty years were randomly assigned to treatment group (Surya Namaskar practice) (n=15) and control group (n=15). The treatment group performed Surya Namaskar practice for six weeks, while the control group did not participate in any treatment other than their regular activities for six weeks. Back flexibility and lumbar flexion of the subjects were assessed at the baseline and after six weeks.

Results. Back flexibility and lumbar flexion increased in the treatment group after six weeks of Surya Namaskar practice.

Conclusions. The current Surya Namaskar procedure contributes to the kinanthropometric well-being of male college students in terms of back flexibility and lumbar flexion. Surya Namaskar should be included in school and college curriculum because of its numerous physical and physiological benefits.

Keywords: yoga, Surya Namaskar, back flexibility and lumbar flexion.

Introduction

Physical education programs have been a part of ancient cultures, including those in the Indian subcontinent, since antiquity. These programs have covered topics such as health, motor skills, military effectiveness, sports and leisure games, medical therapy, physical rehabilitation, and spiritual development (Deshpande, 2013). It is estimated that yoga originated between 4,000 and 8,000 years ago in the northwest Indian region of the Indus Valley civilization. Yoga is a traditional practise that aims to improve a person's physical, mental, emotional, and spiritual well-being (Ross & Thomas, 2010). The meaning of the word yoga is union, joining, or linking as a single entity. Yoga is the art and science of uniting body, mind, and soul by resolving the inherent opposition in all things (Oliver, 2005). Eventually, publications in the fields of physiology and medicine began to use yoga's techniques and methods (Khalsa et al., 2016).

As the words Surya and Namaskara respectively mean "Sun" and "Salutation" or "to greet," Surya Namaskara is a customary yoga pose meant to honour the Sun. It is therefore 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 (Vaibhav et al., 2016).

A set of asanas known as Surya Namaskar have precise breathing patterns. Every single cell in the body is revitalised

by it, and it also provides mental clarity, physical strength, and flexibility (Saraswati, 1983). A series of 12 asanas (postures) make up Surya Namaskar. The entire body is profoundly stretched by these alternating backward and forward bending postures, which flex and stretch the spinal column through its maximum range (Nandar, & Raj, 2014).

A sedentary lifestyle, physical inactivity, or fat accumulation around the joints that limits full range of motion are some of the causes of reduced flexibility. Keeping the body flexible may help to lessen the stiffness and tension that can lead to long-term, frequently fatal medical problems. Surya Namaskar's profound effects on the body allow it to alter kinanthropometric and physiological aspects of the body on its own. Therefore, the purpose of this study was to determine how college-aged men's lumbar flexion and back flexibility were affected by suryanamaskar practice.

Hypothesis. We will presume that by following the surya namaskar routine, we will achieve better back flexibility and lumbar flexion. The hypothesis argued in this paper is that college men students can significantly increase the back flexibility and lumbar flexion by practicing suryanamaskar over a consecutive six weeks period. As a result, the goal of this study was to look into the changes in parameters that occurred during a six-week surya namaskar regimen in thirty college men.

Materials and methods

Search engines used to locate published articles included MEDLINE, EMBASE, Scopus, Science Direct Databases Directory of Open Access Journals (DOAJ), PubMed, and Google Scholar. The terms "Yoga", "Surya Namaskar", "flexibility", "lumbar flexion", and the conjunctions "OR/AND" were used as essential terms. Searches could only be conducted in English. The studies detailing how body flexibility is affected by suryanamasakar are considered for literature review.

Study Participants

Thirty college men from Coimbatore District participated in this study. The selected subjects were divided into two groups. Table 1 below describes the characteristics of the participants. The advantages of the research as well as any possible risks were explained to participants prior to the experiment. They were examined by a qualified physician and all of them were fit for participating in this study.

Table 1. Participants Characteristics (Mean ± SD)

Groups	SNP (G1) n = 15	Control (G2) n = 15
Age (years)	21.20 ± 0.6	21.20 ± 0.7
Height (cm)	174.30 ±4.4	174.20 ± 4.3
Weight (kg)	78.20 ± 5.9	78.20 ± 5.7
BMI (kg/m^2)	25.73 ± 1.32	25.76 ± 1.49

Study organization

An experimental approach with a two-group pretest-posttest design was employed in this investigation. The

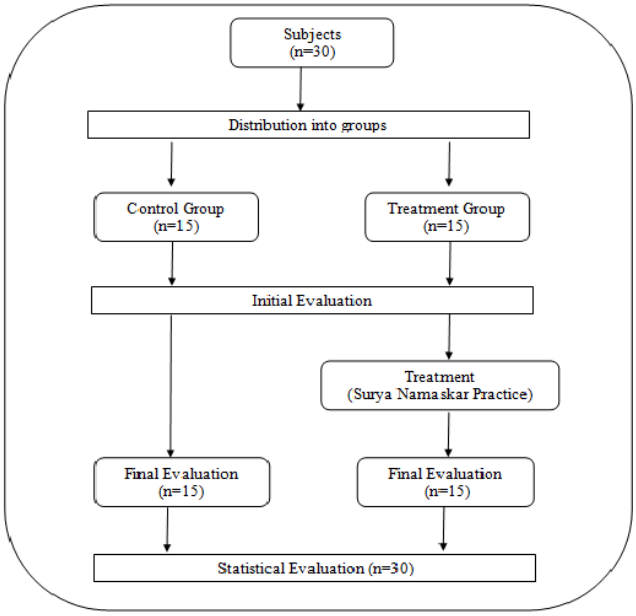

Fig. 1. Flow Diagram

treatment group (n=15) over the course of six weeks, fifteen college men will practice suryanamaskar, and group II was considered as control group (n=15). Participant's informed consents were obtained before the start of the study. Participants were free to withdraw their consent if they felt any discomfort during training programs. All participants were eligible for inclusion in this study because they had no history of musculoskeletal, neurological or orthopaedic disorders that might have affected their ability to perform physical fitness tests, and suryanamasakar practice. There were no dropouts in this study. The procedures followed were in accordance with the ethical standards in compliance with the 1964 Helsinki Declaration and its later amendments.

The Standard protocols were used to test the parameters. The participants warmed up with a five minutes low-intensity aerobic run and a ten minutes active and passive stretching of upper and lower extremity muscles before the experiments.

Anthropometric measurements:

A portable digital scale with a 0.1 kg precision was used to weigh participants who were minimal and did not wear shoes. Using a tape measure and a standard procedure, height was measured. The body mass index (BMI) was computed as follows: weight (kg) divided by height (m^2) squared.

Sit and Reach Test

To evaluate the lower back and hamstring flexibility, participants performed the sit and reach test (Wells and Dillon, 1952). High values of ICC indicate that both versions, the chair sit and reach (0.92–0.96) (Jones et al., 1998) and the back saver sit and reach (0.99) (Patterson et al., 1996), are reliable. An apparatus which had 25 cm mark equivalent to the point where the feet touch the box was used. Participants were asked to warm-up by performing slow stretching exercises. They were asked to "sit barefoot with the legs fully extended with the soles of the feet placed flat against the horizontal cross board of the apparatus, with the inner edge of the sole placed 2 cm from the scale,

Table 2. Surya Namaskar training protocol*

Protocol	Description	Duration
Starting Prayer	"Hiranmayena patrena satyasyapihitam mukham tat tvam pusannapavrunu satyadharmaya drstaye" Oh sun, your golden sphere protects the entrance to the reality like a lid on a vessel.	45 secs
Warm up & Conditioning	Joints stretching and rotation	5-10 mins
Suryanamaskar	Step 1: Hasta uttanasan (Pose with raised arms) Step 2: Padhahastasan (Forward bend when standing) Step 3: Ekapadaprasaranasana (Pose of a horse) Step 4: Dwipadaprasaranasana (Parallel pose with a steep angle) Step 5: Sasankasana (Pose of the moon) Step 6: Sashtanga Namaskar (Salute with eight limbs) Step 7: Bhujangasan (Pose of a cobra) Step 8: Parvatasan (Pose of a mountain) Step 9: Sasankasana (Pose of the moon) Step 10: Ekapadaprasaranasana (Pose of a horse) Step 11: Padhastasan (Forward bend when standing) Step 12: Hasta uttanasan (Pose with raised arms)	10-12 mins
Warm down	Technique for deep relaxation	
Closing Prayer	Ohm Shanti Shanti Shanti	10 secs.

*12 poses – Each pose is held for 5 seconds without a break. Begin with 5 cycles and increase by one every two weeks.

keeping the knees fully extended, arms evenly stretched, and palms down". Participants were then asked to bend and reach forward (without jerking) while pushing the sliding marker along the scale with the fingertips as far forward as possible. They held maximum flexion position for approx. two seconds. The test was performed twice. The trial was not recorded if the knees flexed. The record taken was the max. distance reached to the nearest 0.5 cm.

Updated Schober test

The updated Schober test was used to determine lumbar flexion. The level of S2 was marked at the midpoint between the two PSISs (dimples of the pelvis), and points five centimeters below and ten centimeters above that level were marked. The subject is asked to flex forward after measuring the distance between the three lines, and the distance is measured again. The variation between the two scales indicates how much flexion in the lumbar spine is occurring (White & Norkin, 2011).

Training Protocol

The training was delivered over the course of forty five to sixty minutes in each session. The surya namasakar exercises consisted of a five minutes preparation and a five minutes relaxation procedure. The participants were given the protocol for a total of six weeks, five days per week (Table 2).

Intervention Procedure

Following the pre-test, one hour instruction session was provided to the intervention group to teach them the fundamental postures of the suryanamaskar. It was instructed to the subjects to breathe naturally. To follow the natural breath, focus on each inhalation and exhalation for the assigned amount of time. For the duration of one breath, or exhalation, depending on the exercise, subjects were instructed to hold each posture during the routine. The subjects were provided written instructions for each posture along with an online video of a certified yoga instructor performing suryanamaskar, to aid in their understanding of the routine.

Statistical Analysis

In this study, there were two components to the data analysis process: the Shapiro-Wilk prerequisite test and the Paired Sample T-Test hypothesis test. A paired sample t-test hypothesis test is used in this investigation. The purpose of this test is to compare the outcomes of the pretest and post-test. IBM SPSS Statistics 16.0 was utilised for statistical analysis in this investigation (SPSS, Inc., Chicago, IL, USA).

Results

A total of 30 days of practice were used in this six-week study, which included one pretest, 28 treatments, and one post-test. Up to fifteen male college students are involved. The following are the findings from the computation of lumbar flexion and back flexibility.

Table 3. Normality test*

Groups	Variable	Tests	Shapiro-Wilk		
			Statistic	df	Sig.
EG	Back flexibility	Pre	0.91	15	0.11
		Post	0.91	15	0.11
	Lumbar Flexion	Pre	0.89	15	0.08
		Post	0.88	15	0.05
CG	Back flexibility	Pre	0.89	15	0.05
		Post	0.89	15	0.06
	Lumbar Flexion	Pre	0.88	15	0.06
		Post	0.89	15	0.07

* The data are displayed as means ± SD and sig. value; if the sig. ≥ 0.05, the data are considered normally distributed.

The results of the pretest and posttest for the treatment group as well as the control group were obtained using the Shapiro-Wilk test instrument, based on the results of table 3 above. Each and every value is ≥ 0.05. The paired sample t-test in parametric statistics was then used to test the hypothesis because all of the research results' data were normally distributed.

Table 4. Paired Sample t Test

Variables	Group	Test	Mean ± SD	t	Sig. 2 tailed
BF	CON	Pre	30.40 ± 0.83	1.47	0.164
		Post	30.27 ± 0.88		
	EXP	Pre	30.47 ± 1.13	17.75*	0.000
		Post	33.47 ± 1.12		
LF	CON	Pre	6.27 ± 0.88	0.22	0.827
		Post	6.33 ± 0.96		
	EXP	Pre	6.80 ± 1.42	3.86*	0.002
		Post	8.20 ± 0.86		

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

Table 4 indicates that in the treatment group, the obtained 't' values on variables were 17.75 (Back Flexibility) and 3.86 (Lumbar Flexion). These values were found to be statistically significant at the 0.05 level of confidence for degrees of freedom1 and 14. They were higher than the minimum table value of 2.14. The obtained 't' ratios between pre- and post-test in the control group were 1.47 (Back Flexibility) and 0.22 (Lumbar Flexion) which were less than the necessary table value of 2.14 and were found to be not statistically significant.

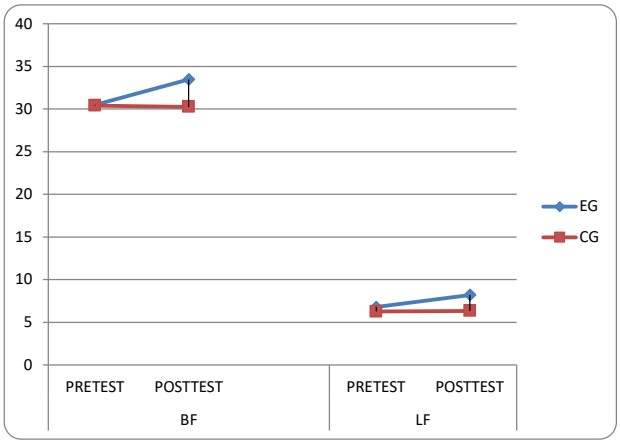

Fig. 2. Bar diagram displays the pre- and post-test results for the treatment and control groups for lumbar flexion (LF) and back flexibility (BF)

Discussion

This study assesses the impact of suryanamaskar practice on lumbar flexion and back flexibility in college men. According to our findings, Suryanamasakar practice for six weeks improved back flexibility and lumbar flexion in college men students. Other research studies have found that suryanamaskar practice improves important kinanthropometric parameters.

Time is often considered a constraint when it comes to exercising, so for those who struggle with time management, doing Surya Namaskara, or "salute to the sun", every day, may be the ideal solution (Saraswati, 2004). Flexibility variations can lead to a variety of biomechanical changes in joints and altered postures. Accordingly, flexibility is necessary to perform daily tasks with ease.

These findings are in line with those of previous studies, which demonstrated a significant increase in back and lumbar flexibility. An investigation comparing the effects of Surya Namaskar and dynamic stretching on hamstring flexibility in physiotherapy students found that Surya Namaskar is superior to dynamic stretching in terms of enhancing hamstring flexibility (Mangaonkar et al 2018). Comparable results were established by Sisodia (2017), discovered that the pace 2 group, pace 4 group, and control group had average versatility of 24.95 ±2.60 cm, 26.70 ±2.03 cm, and 21.20 ±3.15 cm, in that order. This indicates that practicing suryanamaskar, which increases hip joint flexibility, lower back flexibility, and posterior thigh muscle flexibility, can result in either hyperextension or flexion of the hip joint.

Suryanamaskar is said to improve general health and fitness and offer benefits in asana and pranayama (Borker, & Pednekar, 2003). It was shown that hamstring flexibility and muscular endurance were greatly enhanced by Suryanamaskar (Singh et al., 2010). It has also been shown that suryanamaskar improves muscle endurance, upper body strength, and hamstring flexibility (Fondran, 2008). The superficial back line contracts in tandem with the superficial front line during suryanamaskar. Whereas dynamic stretching solely targets the targeted muscle and joint, back contraction strengthens all of the muscles in the back and even the smallest ones in the spinal column. Suryanamaskar stimulates the circulation of blood in the vertebral region, which in turn stimulates the nerves there. Apart from the hamstrings, suryanamaskar enhances and preserves the flexibility of the spine. Based on the findings of this research, suryanamaskar practice has beneficial effects on the kinanthropometric parameters of college men.

Limitations

The small sample size and narrow age range of the study are among its limitations, which limit how broadly the study's conclusions can be applied. Moreover, gender-related differences in the results and related factors could not be examined because the sample did not contain any college women.

Future Recommendations

With a larger sample size, long-term effects of suryanamaskar can be studied. Furthermore, more research is required to determine the effectiveness of Surya Namaskar as a strategy for enhancing physical health and quality of life aspects in a range of medical conditions. An analysis that is longitudinal can also be carried out. It is feasible to

look into how suryanamaskar affects injury frequency and athletic performance. Because of Surya Namaskar, other motor fitness variables can also be investigated.

Conclusions

Surya Namaskar is an easy process that anyone with a little adaptability can perform and has no negative effects. Today's college men have very little time for their personal well-being in between their coursework. Thus, maintaining their general health can be facilitated by performing a few Surya Namaskar cycles daily.

It was evident from the study's limitations and the findings that college-aged men who practiced suryanamaskar five days a week for six weeks saw improvements in their lumbar flexion and back flexibility. These kinds of yoga practices are beneficial for people who want to improve their kinanthropometric, physical, and physiological performance.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Вплив шеститижневого курсу практики сур'я-намаскара на розвиток гнучкості спини та згинання поперекового відділу хребта у студентів коледжу чоловічої статі

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 6 с., 4 табл., 2 рис., 17 джерел.

Мета дослідження. Інтенсивна програма комплексу вправ сур'я-намаскара набула значної популярності серед сучасних практиків йоги. Особливе поєднання методик йогівського дихання, асан (поз) і дхарани (сфокусованої концентрації свідомості) сприяє покращенню показників гнучкості. Метою цього дослідження було вивчити ефективність оригінального шеститижневого курсу сур'я-намаскара на розвиток гнучкості спини та згинання поперекового відділу хребта у студентів коледжу чоловічої статі.

Матеріали та методи. Тридцять студентів коледжу чоловічої статі віком від вісімнадцяти до двадцяти років були рандомізовані до основної групи (практика сур'я-намаскара) (n=15) і контрольної групи (n=15). Основна група виконувала комплекс вправ сур'я-намаскара протягом шести тижнів, тоді як контрольна група не брала участі в жодному курсі тренувань, окрім своїх звичайних видів активності протягом шести тижнів. Гнучкість спини та згинання поперекового відділу хребта у досліджуваних осіб оцінювали на початковому етапі та через шість тижнів.

Результати. Зростання показників гнучкості спини та згинання поперекового відділу хребта спостерігалося в основній групі дослідження після проведення шести тижнів практики сур'я-намаскара.

Висновки. Сучасна процедура комплексу вправ сур'я-намаскара сприяє покращенню стану кінантропометричних показників у студентів коледжу чоловічої статі з точки зору гнучкості спини та згинання поперекового відділу хребта. Завдяки численним фізичним і фізіологічним перевагам, сур'я-намаскара має бути включена до навчальної програми шкіл та коледжів.

Ключові слова: йога, сур'я-намаскара, гнучкість спини та згинання поперекового відділу хребта.

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Assessment of Motor Fitness Metrics among Athletes in Different Sports: An Original Research

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Abstract

Background. Motor fitness is one of the keys to athletes' success and is the initial factor mixed with game-specific technique and tactics that has an impact on game performance. All athletes should incorporate these elements into their sport and game actions.

Study purpose. The aim of this study was to evaluate differences in motor fitness metrics among university-level male athletes participating in various sports.

Materials and methods. Sixty (60) male athletes, ranging in age from 18 to 25 years, were selected from six different sports: Athletics, Basketball, Cricket, Football, Handball, and Volleyball. Each group consisted of 10 athletes who had competed at the inter-university level. The research focused on six key fitness metrics: agility, speed, power, arm strength, abdominal muscle strength, and cardiovascular endurance. Appropriate testing methods and instruments were used to measure these parameters. Statistical analysis, including one-way ANOVA and post hoc LSD tests, was performed to identify significant differences between the groups. A significance level of 0.05 was set for the study.

Results. The results showed statistically significant differences among the groups in agility ($F_{(5,54)} = 4.776$, $p<0.001$), speed ($F_{(5,54)} = 5.602$, $p<0.000$), and cardiovascular endurance ($F_{(5,54)} = 3.578$, $p<0.007$). However, no significant differences were observed for power ($F_{(5,54)} = 2.079$, $p>0.082$), arm strength ($F_{(5,54)} = 1.368$, $p>0.251$), and abdominal muscle strength ($F_{(5,54)} = 1.947$, $p>0.102$). According to the post hoc (LSD) test findings, each group's agility, speed, and cardiovascular endurance parameters were compared to each other to check the significance level.

Conclusions. In summary, the study has revealed that agility, speed, and cardiovascular endurance were significantly different among athletes in various sports, whereas power, arm strength, and abdominal muscle strength were not. The findings suggest that athletes and coaches should prioritize sport-specific fitness components to improve game performance.

Keywords: athletes, motor fitness, team sports, performance.

Introduction

Motor fitness has multiple benefits for physical, mental, and psychosocial health and is a crucial aspect of assessing an individual's physical capability, particularly in athletes, which includes various components of agility, balance, coordination, strength, reaction time, and speed (Kohl & Cook, 2013; Kumar & Kumar, 2011). Motor fitness evaluations play an important role in assessing adult health, as they are closely linked to cardiovascular issues, susceptibility to falls, cognitive decline, mobility challenges, difficulties in daily tasks, and overall mortality risk (Castro-Piñero et al., 2023). It has been recognized that maintaining motor fitness is essential to counteract the age-associated decline in physical capabilities, ensuring a good quality of life for the elderly (Rikli & Jones, 1999). For athletes, in particular, the

level and type of physical fitness required can vary greatly depending on the specific demands of their sport. Different sports have distinct physical demands, and as such, optimal fitness criteria can differ significantly from one sport to another. Team sports, such as handball, football, volleyball, and basketball, contribute to increasing various fitness aspects like speed and strength (Pandey & Sardar, 2015). In basketball, agility and jump metrics assess players' physical skills (Hoffman et al., 1996). Similarly, soccer uses the Yo-Yo intermittent recovery test to assess aerobic capacity during intense exercise (Krustrup et al., 2003). Research indicates that genetics, training, and motor fitness are interconnected in athletes (Bouchard & Malina, 1983). A player's physical fitness level is influenced by the characteristics of the game and external traits. These traits, influenced by genetics, nutrition, and training level, significantly affect an athlete's performance (Begum, 2019). Strength training is particularly effective in increasing physical performance (Stølen et al., 2005; Ziv & Lidor, 2010), and muscle strength requires regular flexibility training (Rahman & Islam, 2020).

Sports not only benefit the players but also affect society and nation-building, as physical fitness is important for individual health, development, and the security of a country (Kumar, 2021; Kumar & Kumar, 2011). As sports have become more commercial, athletes are placing greater emphasis on their physical condition and performance (Babu, 2013). Different sports require specific sets of physical abilities. For all ball game players, having maximal isometric strength, including explosive strength and power, is essential to achieving ball-game skills (Rahman & Sharma, 2023). For example, while basketball, soccer, and tennis athletes prioritize motor fitness components, particularly speed, agility, endurance, and changing directions quickly on the field as the game demands (Sheppard & Young, 2006; Kumar & Singh, 2018; Islam, 2018). Volleyball demands strength and coordination for serving and spiking (Suharjana et al., 2020), while basketball necessitates a blend of speed, endurance, and agility (Metgud et al., 2019; Tiwari et al., 2012). Even in cricket, various components of physical fitness, such as muscle strength and agility, are crucial (Ghosalkar et al., 2020). In ball games, especially soccer and handball, players must have quick reflexes, as it is unusual to switch offensive and defensive positions (Bansod, 2018; Islam & Kundu, 2020). Endurance is a key component common to almost all sports, especially football and basketball, that require sustained physical activity (Singh & Thapa, 2015). Different sports prioritize different aspects of conditioning programme, but it remains a fundamental factor for improved athletic performance (Lee et al., 2020). Sports that require rapid directional changes, such as American football and basketball, place a high emphasis on agility (Zemková & Hamar, 2014). Moreover, optimum motor fitness in youth can foster lifelong physical activity habits, reducing the risks associated with sedentary lifestyles (Lubans et al., 2010). Individuals with high motor fitness levels also show better cognitive functioning, power of mental imagination, and overall quality of life (Best, 2010; Rahman & Islam, 2021). In essence, motor fitness is fundamental for athletes, highlighting its multifaceted nature, including strength, speed, agility, endurance, and coordination (Clark et al., 2010).

Athletic performance is greatly influenced by game specific fitness, which are key elements to success in any sport. All athletes need essential motor fitness components for their respective activities. Although fitness varies from sport to sport, basic motor fitness is the same for every player. However, university-level players have access to similar practices, so their basic fitness is roughly the same. The aim of this study was to evaluate the motor fitness components of different team athletes participating in university-level sports.

Materials and methods

Participants

Sixty (N=60) male athletes from Jashore University of Science and Technology, located in Jashore district, Bangladesh, were randomly selected for the study. Each group consisted of ten (n=10) players aged 18 to 25, representing six different sports: athletics, basketball, cricket, football, handball and volleyball. All were competitors in Inter-University games.

Variables and Criterion Measures

Six (6) essential fitness indicators were the focus of the study: cardiovascular endurance, abdominal muscle strength, arm strength, speed, agility and power. These parameters were measured with proper equipment and testing techniques.

Test Procedure

The shuttle run test is used extensively and appears to be a useful field test for evaluating high intense capacity of

Table 2. Variables and criterion measures

Variables	Test items	Unit of measure
Agility	4 × 10 m SR	Second (s)
Speed	50 m sprint	Second (s)
Power	SBJ	Meter (m)
Arm strength	PU	Number (n)
Abdominal muscle strength	60s. SU	Number (n)
Cardiovascular endurance	Cooper/12 minutes run	Meter (m)

SR= Shuttle Run, SBJ= Standing Broad Jump, PU= Pull-up, SU= Sit-up

Table 1. Characteristics of the subjects

Variables	Athletics	Basketball	Cricket	Football	Handball	Volleyball
Age (years)	20.40±1.43	21.70±1.34	21.30±1.16	21.20±1.62	21.00±1.15	21.40±1.26
Height (cm)	68.80±2.10	76.30±5.44	70.70±2.31	72.90±3.48	66.60±4.45	74.90±3.28
Weight (kg)	174.00±4.94	181.30±5.52	175.00±3.16	177.20±2.39	172.10±4.48	180.20±2.53
BMI (kg/m^2)	22.80±1.69	23.18±0.87	23.11±0.96	23.21±0.72	22.58±1.02	23.02±0.79

the sports person. The course consists of two lines 10 meters apart and two cones placed on opposite sides of the starting line. Each subject ran a marked area 4x10 m long at a set increasing speed (Verschuren & Takken, 2010). Participants were tested for speed using a 50-meter sprint, where they were asked to run as fast as possible in a straight line. The test was conducted twice, timed to the nearest 0.1 seconds, with the best time noted (Shang et al., 2010). The standing broad jump (SBJ) is a reliable test used to assess lower limb strength and power. Participants stand with their heels on a line, then jump horizontally as far as they can without specific instructions on leg or arm movements. After landing with both feet together, the jump's distance is measured from the start line to the heel nearest the start (Thomas et al., 2020). For the PUT, participants began by holding their arms fully extended and their shoulders completely flexed for a duration of 2 seconds. To count as a valid rep, the upper part of the jawbone had to go above the level of the bar. After that, participants needed to return to the starting position to finish the rep. Techniques like swinging, kipping, or continuous bouncing from the lowest point were not permitted (Coyne et al., 2015). The SUT assesses the stamina of the abdominal muscles, requiring the participant to complete the maximum number of sit-ups in a minute. The participant starts by lying flat on their back with their knees bent at a 90-degree angle. Their hands should be positioned behind their heads, with their elbows extended directly out in front. A proper sit-up is counted when the elbows meet the knees and then return to a position where the shoulders are in contact with the floor (Blomqvist et al., 2013). The Cooper 12-minute run test serves as a quantitative assessment of an individual's aerobic capacity and cardiovascular fitness. By setting markers at specific points around a track, the distance covered in a 12-minute period can be measured. Participants are required to walk or run during this period, and the cumulative distance they traverse is noted down (Cooper, 1968).

Table 3. Descriptive statistics on fitness components

Parameters	Groups	N	Mean	Std. Deviation	Std. Error	Minimum Value	Maximum Value
Agility	Athletics	10	9.46	0.29	0.09	9.10	9.90
	Basketball	10	9.70	0.58	0.18	8.60	10.70
	Cricket	10	10.20	0.32	0.10	9.50	10.51
	Football	10	9.57	0.48	0.15	9.05	10.50
	Handball	10	9.95	0.46	0.14	9.30	10.80
	Volleyball	10	10.09	0.38	0.12	9.35	10.65
Speed	Athletics	10	6.48	0.51	0.16	5.43	7.08
	Basketball	10	6.95	0.30	0.10	6.59	7.62
	Cricket	10	7.30	0.29	0.09	6.88	7.91
	Football	10	6.73	0.25	0.08	6.46	7.27
	Handball	10	6.90	0.50	0.16	6.14	7.75
	Volleyball	10	7.16	0.44	0.14	6.52	8.00
Power	Athletics	10	2.39	0.22	0.07	2.00	2.80
	Basketball	10	2.46	0.12	0.04	2.25	2.65
	Cricket	10	2.31	0.17	0.05	1.91	2.52
	Football	10	2.51	0.14	0.04	2.25	2.70
	Handball	10	2.39	0.13	0.04	2.20	2.60
	Volleyball	10	2.47	0.15	0.05	2.24	2.73
Arm Strength	Athletics	10	11.50	5.56	1.76	2.00	20.00
	Basketball	10	9.40	2.76	0.87	3.00	13.00
	Cricket	10	8.40	1.65	0.52	7.00	12.00
	Football	10	10.60	2.84	0.90	7.00	14.00
	Handball	10	9.60	1.71	0.54	8.00	13.00
	Volleyball	10	8.60	3.10	0.98	3.00	14.00
Abdominal Strength	Athletics	10	42.10	8.44	2.67	28.00	53.00
	Basketball	10	43.60	9.31	2.94	30.00	60.00
	Cricket	10	37.60	8.09	2.56	26.00	51.00
	Football	10	41.40	6.72	2.12	34.00	52.00
	Handball	10	44.50	7.92	2.50	36.00	60.00
	Volleyball	10	35.30	7.97	2.52	22.00	46.00
Cardiovascular Endurance	Athletics	10	2721.00	274.37	86.76	2140.00	3220.00
	Basketball	10	2605.50	240.26	75.98	2190.00	3000.00
	Cricket	10	2294.00	355.75	112.50	1820.00	2850.00
	Football	10	2715.50	99.01	31.31	2600.00	2920.00
	Handball	10	2504.20	236.69	74.85	2025.00	2790.00
	Volleyball	10	2474.00	347.79	109.98	1900.00	3200.00

Table 4. Fitness testing of various disciplines was carried out using the ANOVA

Parameters	Groups	Sum of Squares	df	Mean Square	F-Value	Sig. Level
Agility	Between Groups	4.40	5	0.88	4.776*	.001
	Within Groups	9.95	54	0.18		
Speed	Between Groups	4.39	5	0.88	5.602*	.000
	Within Groups	8.46	54	0.16		
Power	Between Groups	0.27	5	0.05	2.079	.082
	Within Groups	1.39	54	0.03		
Arm Strength	Between Groups	70.48	5	14.10	1.368	.251
	Within Groups	556.50	54	10.31		
Abdominal Strength	Between Groups	640.55	5	128.11	1.947	.102
	Within Groups	3552.70	54	65.79		
Cardiovascular Endurance	Between Groups	1330875.33	5	266175.07	3.578*	.007
	Within Groups	4017112.60	54	74390.97		

*. Significant at 0.05 level

Statistical analysis

The data was analyzed using IBM's SPSS software (version 21 for Windows) to compare different motor fitness metrics. For each group, we calculated the mean, standard deviation, standard error of the mean, as well as the minimum and maximum values. We employed a one-way ANOVA followed by a post hoc LSD test to examine significant differences in the data. A significance level of 0.05 was used for the analyses. To check for data normality, the Shapiro-Wilk test was conducted, confirming that the data followed a normal distribution.

Results

Table 4 shows that there was a significant difference for the parameter namely agility, $F_{(5,54)}$ =4.776, p<0.001; speed, $F_{(5,54)}$=5.602, p<0.000; and cardiovascular endurance, $F_{(5,54)}$=3.578, p<0.007. There was a non-significant difference between the groups for the variable namely power, $F_{(5,54)}$=2.079, p>0.082; arm strength, $F_{(5,54)}$=1.368, p>0.251; and abdominal strength, $F_{(5,54)}$=1.947, p>0.102.

The LSD Post-hoc Test (Table 5) was computed, and in the agility domain, significant differences were found between athletics and cricket (p<0.000), athletics and handball (p<0.014), athletics and volleyball (p<0.002), basketball and cricket (p<0.011), basketball and volleyball (p<0.044), cricket and football (p<0.002), and football and volleyball (p<0.009). In speed, significant differences were found between athletics and basketball (p<0.010), athletics and handball (p<0.020), athletics and volleyball (p<0.000), basketball and cricket (p<0.050), cricket and football (p<0.002), cricket and handball (p<0.028), and football and volleyball (p<0.017). In cardiovascular endurance, significant differences were found between athletics and cricket (p<0.001), athletics and volleyball (p<0.048), basketball and cricket (p<0.014), and cricket and football (p<0.001).

Discussion

In the present study, Table 4 indicates significant differences in agility, speed, and cardiovascular endurance between groups, but no significant differences in power, arm strength, and abdominal strength. Existing studies present a mixed view of differences in fitness ability across sports. For example, handball and basketball players have been found to be similar in terms of speed and agility (Phatangare, 2019).

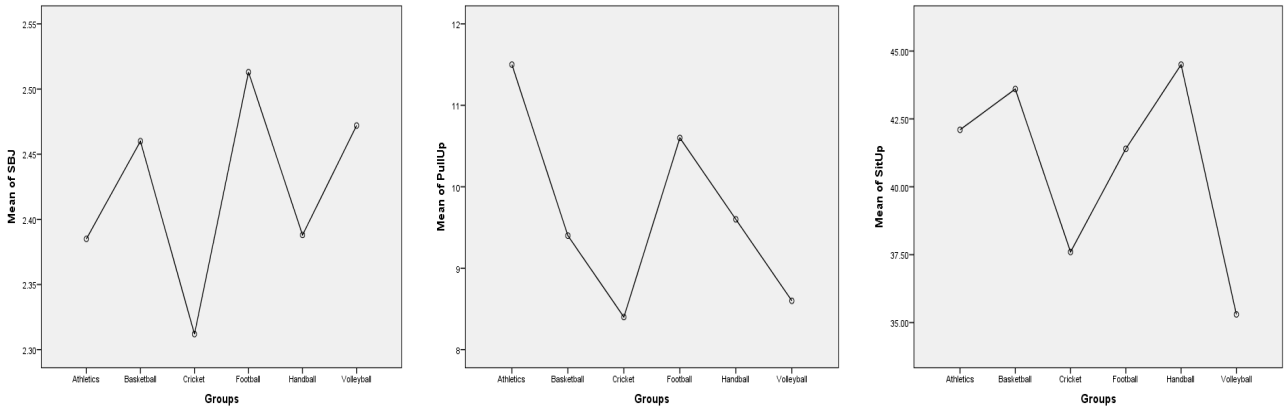

Fig. 1. Mean plots of not significant variables

Table 5. LSD Post-hoc Test

Parameters	Groups	Groups	Mean Difference	Std. Error	Sig. Level
Agility	Athletics	Basketball	0.23	0.19	0.228
		Cricket	0.73700*	0.19	0.000
		Football	0.11	0.19	0.576
		Handball	0.48700*	0.19	0.014
		Volleyball	0.63000*	0.19	0.002
	Basketball	Cricket	0.50300*	0.19	0.011
		Football	0.13	0.19	0.514
		Handball	0.25	0.19	0.193
		Volleyball	0.39600*	0.19	0.044
	Cricket	Football	0.62900*	0.19	0.002
		Handball	0.25	0.19	0.198
		Volleyball	0.11	0.19	0.580
	Football	Handball	0.38	0.19	0.053
		Volleyball	0.52200*	0.19	0.009
	Handball	Volleyball	0.14	0.19	0.460
Speed	Athletics	Basketball	0.47000*	0.18	0.010
		Cricket	0.82500*	0.18	0.000
		Football	0.25	0.18	0.164
		Handball	0.42600*	0.18	0.020
		Volleyball	0.68500*	0.18	0.000
	Basketball	Cricket	0.35500*	0.18	0.050
		Football	0.22	0.18	0.219
		Handball	0.04	0.18	0.805
		Volleyball	0.21	0.18	0.230
	Cricket	Football	0.57500*	0.18	0.002
		Handball	0.39900*	0.18	0.028
		Volleyball	0.14	0.18	0.433
	Football	Handball	0.18	0.18	0.325
		Volleyball	0.43500*	0.18	0.017
	Handball	Volleyball	0.26	0.18	0.149
Cardiovascular Endurance	Athletics	Basketball	115.50	121.98	0.348
		Cricket	427.00000*	121.98	0.001
		Football	5.50	121.98	0.964
		Handball	216.80	121.98	0.081
		Volleyball	247.00000*	121.98	0.048
	Basketball	Cricket	311.50000*	121.98	0.014
		Football	110.00	121.98	0.371
		Handball	101.30	121.98	0.410
		Volleyball	131.50	121.98	0.286
	Cricket	Football	421.50000*	121.98	0.001
		Handball	210.20	121.98	0.091
		Volleyball	180.00	121.98	0.146
	Football	Handball	211.30	121.98	0.089
		Volleyball	241.50	121.98	0.053
	Handball	Volleyball	30.20	121.98	0.805

*. The mean difference is significant at the 0.05 level

Similarly, Shukla et al. (2020) found that collegiate soccer and cricket players did not differ significantly in muscular endurance, speed, or agility, although they did differ significantly in overall physical fitness and variable muscle strength. In a study by Keshav and Harmandeep (2014) pull-ups, sit-ups, a 50-meter dash, and 600-meter run showed no significant differences between the two unspecified groups, although the shuttle run did. Handball and volleyball players differed in speed but not in agility (Akilan & Shah, 2014), thereby contradicting the findings of those who noted significant agility differences between these two groups of athletes (Sharma & Hussain, 2019). In sports as diverse

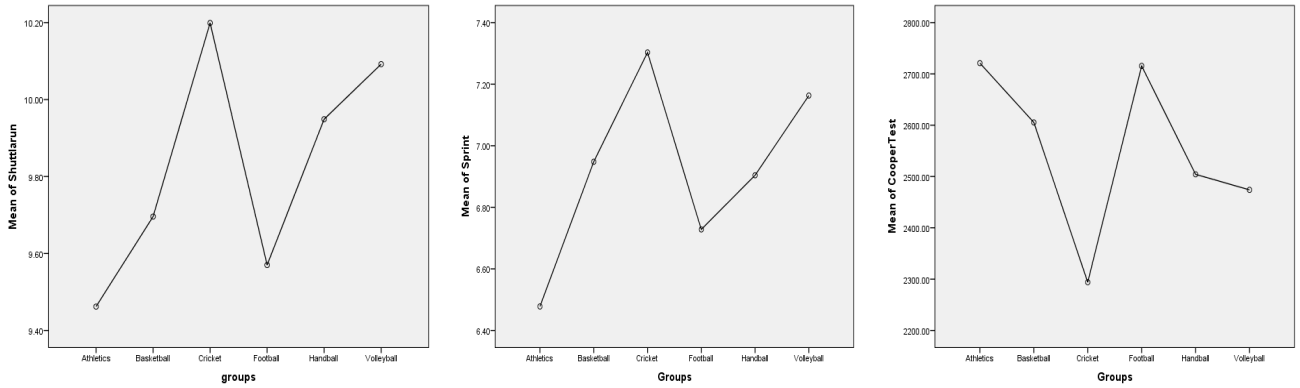

Fig. 2. Mean plot of significant variables

as track and field, basketball, handball, soccer, badminton and kabaddi, athletes outperform their counterparts in cardiovascular endurance. However, all groups showed similar results in arm strength (Reza et al., 2022).

When it comes to speed and agility, Kumar and Singh (2018) reported individual differences between football, handball and volleyball players, but noted that football and cricket players did not differ in these metrics (Mandal et al., 2017). Research found no differences in leg strength between soccer players and middle-distance runners, although there were differences in speed and arm strength (Umesh, & Kumar, 2017). The study observed no significant differences in strength and endurance between basketball and football players (Singh & Thapa, 2015). There is no significant difference in cardio-respiratory fitness between football, basketball and handball players (Singh & Singh, 2017). A study found that football and handball players in Haryana differed significantly in arm and abdominal strength (Devi & Kumar, 2022). Finally, Kumar and Kumar (2011) noted significant differences in cardiovascular endurance, agility and muscular endurance between basketball and volleyball players. The results found that cricket and volleyball players differed significantly in aerobic endurance, agility, speed and strength but not in arm or abdominal strength (Chaudhary, 2020).

Conclusions

Athletes in various sports show differences in agility, speed, and cardiovascular endurance but no differences in power, arm strength, and abdominal muscle strength. To improve performance and gain a competitive advantage, athletes and coaches should focus on sport-specific fitness training. Further research could explore this effect at higher competition levels. The majority of Bangladeshi university athletes, according to the authors, follow the same practices, despite the fact that each game requires a different set of motor fitness measures. The findings demonstrated that for improved gaming performance, each player should give priority to the motor fitness parameters specific to their respective game.

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Conflicts of interest

The authors declare no conflicts of interest.

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Оцінка показників рухової підготовленості серед спортсменів у різних видах спорту: оригінальне дослідження

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 9 с., 5 табл., 2 рис., 48 джерел.

Історія питання. Рухова підготовленість є однією з ключових складових успішності спортсменів і є початковим фактором, який у поєднанні з технікою і тактикою конкретної гри впливає на результативність гри. Всі спортсмени повинні включати дані елементи до своєї спортивно-ігрової діяльності.

Мета дослідження. Метою цього дослідження було оцінити відмінності в показниках рухової підготовленості серед спортсменів-чоловіків університетського рівня, які займаються різними видами спорту.

Матеріали та методи. Для дослідження було відібрано шістдесят (60) спортсменів чоловічої статі, віком від 18 до 25 років, які представляли шість різних видів спорту: Легка Атлетика, Баскетбол, Крикет, Футбол, Гандбол та Волейбол. Кожна група складалася з 10 спортсменів, які змагалися на міжуніверситетському рівні. У фокусі дослідження були шість ключових показників фізичної підготовленості: спритність, швидкість, продуктивність, сила рук, сила м'язів черевного преса та витривалість серцево-судинної системи. Зазначені параметри вимірювалися за допомогою відповідних методів тестування та інструментів. Для встановлення значущих відмінностей між групами було проведено статистичний аналіз, включаючи однофакторний дисперсійний аналіз ANOVA та post-hoc аналіз з використанням LSD-тесту (найменша значуща різниця). У дослідженні був встановлений рівень значущості 0,05.

Результати. За результатами дослідження зафіксовано статистично значущі відмінності серед груп у показниках спритності ($F(5,54) = 4,776$, $p<0,001$), швидкості ($F(5,54) = 5,602$, $p<0,000$) та витривалості серцево-судинної системи ($F(5,54) = 3,578$, $p<0,007$). Однак не спостерігалося значущих відмінностей для показників продуктивності ($F(5,54) = 2,079$, $p>0,082$), сили рук ($F(5,54) = 1,368$, $p>0,251$) і сили м'язів черевного преса ($F(5,54) = 1,947$, $p>0,102$). Відповідно до резуль-

татів post-hoc аналізу з використанням LSD-тесту, для перевірки рівня значущості було проведено порівняльний аналіз параметрів спритності, швидкості та витривалості серцево-судинної системи в кожній групі.

Висновки. Таким чином, дослідження виявило, що показники спритності, швидкості та витривалості серцево-судинної системи суттєво відрізняються між спортсменами в різних видах спорту, тоді як показники продуктивності, сили рук та сили м'язів черевного преса не мають відмінностей. Отримані дані свідчать про те, що спортсмени та тренери повинні надавати пріоритет компонентам фізичної підготовленості, що є специфічними для конкретного виду спорту з метою покращення результативності гри.

Ключові слова: спортсмени, рухова підготовленість, командні види спорту, результативність.

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Effects of Whole-Body Vibration Combined with Blood Flow Restriction and Systemic Hypoxia on Body Composition and Physical Performance in Overweight University Students

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Abstract

Study purpose. This study investigated the effects of whole-body vibration (WBV) combined with blood flow restriction (BFR) and hypoxic exposure (HYP) on body composition and physical performance in overweight university students.

Materials and methods. Twenty-nine male university students with overweight were divided into 3 groups: 1) whole-body vibration (WBV), 2) whole-body vibration plus blood flow restriction (WBV+BFR, 60% of occlusion pressure) and 3) whole-body vibration plus hypoxic exposure (WBV+HYP, FiO_2 = 15.8%). Training included 10 sets of intermittent WBV exercise (30-35 Hz in frequency and high amplitude) 20 min/day and 3 days/week. Body composition along with physical performance was measured before (2-3 days prior) and after (2-3 days post) an 8-week training period.

Results. The results of this study were as followed, after training, the maximum strength (1RM) in the leg press and leg curl were significantly increased in the WBV+HYP group (28.31%, p = 0.016 and 13.56%, p = 0.017) compared with the WBV group (17.68% and 2.88) respectively. Similarly, the WBV+HYP group showed a substantial increase in muscle endurance in the leg extension and leg curl (28.57%, p = 0.013 and 34.38% p = 0.049) when compared to the WBV group (5.33% and 13.20%) respectively.

Conclusions. Whole-body vibration combined with blood flow restriction and hypoxic exposure were effective in improving body composition and physical fitness. Performing the procedure can also be adjusted according to convenience and suitability for each individual. It is a guideline for preventing, treating, and promoting health among overweight adolescents.

Keywords: whole-body vibration, blood flow restriction, systemic hypoxia, body composition, physical performance, overweight.

Introduction

Whole-body vibration machine is an exercise machine designed to increase muscle activation in the form of vibration with frequency and amplitude. The duration of vibration can be set for each training session. At present, whole-body vibration machine is popular and used more in medical, health and fitness fields. The main goal of its use is to improve physical performance (Park et al., 2015), especially muscular strength and power (Bosco et al., 1999) with a variety of training, such as static and dynamic training and a combination of static and dynamic training. The exercises for this machine can be designed in a variety of ways to suit the user and the training goals. However, different configurations of whole-body vibration parameters will produce different results (Luo et al., 2005).

Exercise training combined with blood flow restriction applies a tourniquet on the upper extremities of the body, i.e., the upper arms and legs. Low-load resistance training with blood flow restriction (Pearson & Hussain, 2015) at 20-30% 1RM can stimulate muscle development comparable to that of the traditional high-load resistance training at 70-80% 1RM (Kim et al., 2017; Manimmanakorn et al., 2013; Vechin et al., 2015). Previous studies investigated the acute effects of whole-body vibration combined with blood flow restriction. It was found that there was an increase in the EMG values from the rectus femoris and vastus lateralis (Cai et al., 2018; Centner et al., 2019). A study of long-term exposure to WBV exercise by Cai et al. (2021) investigated the effects of whole-body vibration combined with blood flow restriction on muscle performance with a training period of 8 weeks. The study revealed that thigh muscle mass significantly increased by 3%. Moreover, 1RM leg press and muscle endurance significantly increased when compared with WBV only (Cai et al., 2021). In addition, a study by Centner et al. (2020) performed WBV+BFR training in healthy women. After 10 weeks of training, there was an increase in the muscle cross-sectional area compared to WBV only. While, muscular strength and jump performance were not significantly different between groups (Centner et al., 2020). Therefore, continuous training of WBV+BFR seems to be a training method that can improve muscle mass, strength and endurance among those who have not been trained before or those who have limited exercise at high intensity. However, it needs to be confirmed in future research studies.

Nowadays, altitude/hypoxic training is used to develop the physical performance of athletes. A simulated altitude is used along with various training programs to promote positive adaptation of the body, which can help prevent and treat various diseases (Millet et al., 2016; Verges et al., 2015). Camacho-Cardenosa et al. (2020) conducted a study on the effects of whole-body vibration under hypoxic exposure (FiO_2=16.1%) on muscle mass and functional mobility in older adults. The results showed that after 18 weeks of training, there was no difference in any parameters in the two groups. This may be due to the basic characteristics of the population, the training program and the degree of hypoxia that may be insufficient to contribute to the development of muscle mass and functional mobility (Camacho-Cardenosa et al., 2020). Although, previous studies on WBV + HYP were rarely conducted. Thus, further research should be conducted to determine whether breathing under hypoxia is an effective form of training in therapeutics or if it could be a potentially harmful way. However, it depends on the degree of hypoxia, frequency, duration of training and training programs.

Therefore, the researchers were interested in studying and comparing the effects of whole-body vibration combined with blood flow restriction and hypoxic training on body composition and physical performance of overweight male students.

Materials and methods

Study participants

Twenty-nine male overweight students from Ubon Ratchathani Rajabhat University (mean age 20.17 ± 0.96 years) volunteered for this study. The inclusion criteria were as follows: participants measured and reported as overweight (BMI = 23.0-24.9 kg/m^2), likely to be untrained and no WBV exercise program within the past 3 months, reported no exposure to an altitude of more than 1,000 meters (3,300 feet) within the last 3 months, no history of severe acute mountain sickness and no contraindicative for WBV exercise. Participants provided written informed consent from all the participants after being informed about the study's details, purpose and procedures. The study was approved by Sisaket Rajabhat University Human Ethics Committee (HE661014).

Study organization

The participants were randomly divided into three experimental groups based on the level of oxygen concentration and occlusion pressure: whole-body vibration exercise while breathing room air (normobaric WBV exercise; WBV, n = 10), whole-body vibration plus blood flow restriction (WBV+BFR exercise at 60% of occlusion pressure, WBV+BFR; n = 9) and whole-body vibration exercise plus hypoxic exposure (hypoxic WBV exercise while breathing 15.8% oxygen concentration; WBV+HYP, n = 10). All the participants were measured at baseline and after eight weeks of training (Between 2 to 3 days before and after the last training session) (Fig. 1).

Training program

All groups performed the vibration exercise in a standing position, doing the static squat position at 100° knee flexion on a whole-body vibration (Power plate Pro5 Silver, USA). The whole-body vibration frequency was set at 30 Hz and high amplitude. All participants performed a total of 10 sets, 1 minute each and 1 minute rest between sets. After the 5th set, the participants can rest for 2 minutes between sets. During the rest, they can move freely. In the whole-body vibration plus blood flow restriction group, cuffs (Vald Performance: AirBands, Australia) were wrapped around the thighs (mid-thigh circumference) at 60% of cuff pressure (60% of each individual's arterial occlusion). In the whole-body vibration exercise plus hypoxic exposure group, breathing training was performed using the hypoxicator device (Hypoxicator: altitude training systems-hypoxic unit, Australia) and the oxygen concentration was set at 15.8% (FiO_2 = 15.8%) an altitude ~2200 meter above sea level. After 4 weeks of training, the progressive overload was observed by raising the frequency to 35 Hz for 20 min/day, 3 days/week for a continuous period of 8 weeks. The oxygen saturation (SpO_2) was measured throughout the training period using a finger pulse oximeter (Pulse oximeter by beurer model: po30). The heart rate was measured using a heart rate monitor (Polar H10, Finland) and recorded over the course of the training.

Exercise testing

The data were collected from all three groups before and after 8 weeks of training with the following tests. 1) Body composition test: body weight, BMI, percentage of body fat, fat mass, fat-free mass, skeletal muscle mass (right and left leg) and visceral adipose tissue were measured. The subjects were asked to stand on the machine (body composition;

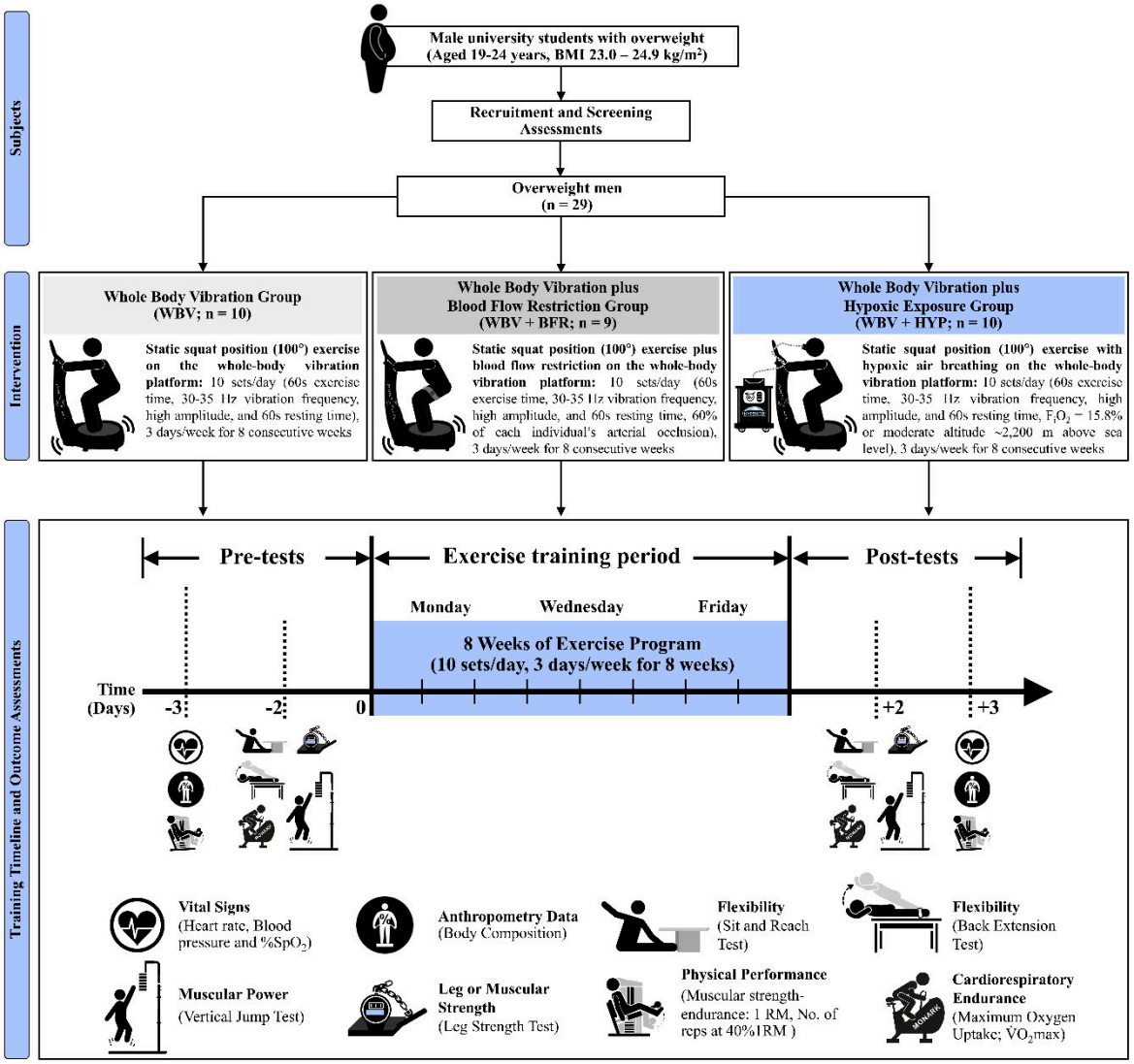

Fig. 1. Outline of training and testing schedule.
Abbreviations: reps, repetition; MHR, maximum heart rate

seca mBCA, Germany) with their shoes off. 2) Flexibility test: Hamstring and lower back muscles were tested with a standing trunk flexion meter (Flexion-D Takei physical fitness test; T.K.K. 5403, Japan), and the trunk muscles were tested by a trunk extension meter (Extension-D Takei physical fitness test; T.K.K. 5404, Japan). 3) Leg strength test: The leg muscular strength was tested by using a back strength dynamometer (Back-A Takei physical fitness test; T.K.K. 5002, Japan). The subjects stood on the machine and bent their knees while grasping the handle of the machine, adjusted the angle of the knee joint to the ready position, applied force from the leg until the chain was fixed and applied the full force until it reached the maximum value. 4) Muscle strength test: Maximum strength (1-Repetition maximum: 1RM) was tested on a stationary machine in knee extension (Nautilus IMPACT S1312, USA), knee flexion (Nautilus IMPACT S1301, USA) and leg press (Nautilus ONE S6LP, USA). The subjects were asked to do 3 exercises using an indirect method and predicted the 1RM value from the equation: 1RM = weight lift / 1.0278 - (0.0278 x reps) (Brzycki, 1988). 5) Muscle endurance test: The number of reps was tested on a stationary machine in knee extension (Nautilus IMPACT S1312, USA) and knee flexion (Nautilus IMPACT S1301, USA). The subjects performed 2 exercises at 40% 1RM and repeated them several times until the force decreased to 60% of the default value. The number of times they can do was recorded. 6) Maximum oxygen uptake test: Cardiorespiratory endurance was tested in an indirect way by cycling according to the Astrand method - rhyming under the supervision of the researcher throughout the assessment (Monark 828E, Sweden). 7) Muscle power: It was tested by using a vertical jump tester (Vertec vertical jump tester, United States). The subjects stood in the starting position and flexed their knees to jump as high as possible (the maximum effort countermovement jump test), using the hands to touch the height indicator bar. The test was performed twice, and

the maximum jump height was recorded. The value of the maximum jump height was subtracted from the value of the height while touching the height indicator bar.

Statistical analysis

Statistical analyses were performed using SPSS 26 (IBM Corp. IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp). Data are presented as mean ± standard deviation (SD). Data normality was evaluated by using the Shapiro-Wilk test. The analysis of covariance (ANCOVA) with a post-hoc Bonferroni adjustment was used to evaluate differences in body composition and physical performance between groups. A paired t-test (comparison between values obtained before and after intervention) was completed. Alpha intervals for all testing were set at $p<0.05$.

Results

The participants characteristics and baseline measured in the 3 training groups are presented in Table 1. No significant differences existed among the groups (WBV, WBV+BFR and WBV+HYP) for any variable.

Eight weeks of whole-body vibration exercise plus hypoxic exposure (FiO_2 = 15.8%) increased skeletal muscle mass and skeletal muscle mass of right leg by 2.90% and 2.82% respectively (Table 2). Despite this increase in the WBV+HYP group, changes in skeletal muscle mass as a result of training (baseline to post-intervention) were not significantly different between groups.

Table 3 shows the mean values of physical performance before and after 8 weeks of training. It was found that the WBV+BFR and WBV+HYP group showed substantially improvement in back extension (9.07% and 10.35% respectively, $p < 0.05$), compared to their baseline (Fig. 2).

In particular, after 8 weeks of training, the maximum strength (1RM) in the leg press and leg curl were significantly increased in the WBV+HYP group (28.31%, $p = 0.016$ and 13.56%, $p = 0.017$) compared with the WBV group (17.68% and 2.88%) respectively (Fig. 3). Similarly, WBV+HYP group showed a substantial increase in muscle endurance in the leg extension and leg curl (28.57%, $p = 0.013$ and 34.38% $p = 0.049$) when compared to the WBV group (5.33% and 13.20%) respectively (Fig. 4). Despite this increase in the whole-body vibration plus hypoxic exposure group, changes in maximum oxygen uptake (29.34 ± 8.53 ml/kg/min and

Table 1. Participants characteristics in the 3 training groups

Characteristics	WBV (n = 10)	WBV+BFR (n = 9)	WBV+HYP (n = 10)
Age (y)	19.70±1.42	20.44±1.01	19.60±1.07
Weight (kg)	83.99±25.49	82.98±13.37	83.56±15.39
Height (cm)	176.70±6.80	171.22±7.28	175.40±4.90
BMI (kg/m^2)	27.53±8.76	28.48±3.39	27.08±4.81
Resting heart rate (b/m)	85.86±9.26	84.17±4.67	81.86±10.64
SpO_2 (%)	98.43±0.53	98.38±0.52	98.56±0.53
SBP (mmHg)	129.75±7.85	127.13±6.81	129.78±8.04
DBP (mmHg)	80.11±13.55	74.11±6.64	72.33±5.61

Description: WBV; whole-body vibration, WBV+BFR; whole-body vibration plus blood flow restriction, WBV+HYP; whole-body vibration exercise plus hypoxic exposure; BMI; body mass index; SpO_2 = resting arterial oxygen saturation; SBP = systolic blood pressure; DBP = diastolic blood pressure. Values are mean ± SD

Table 2. Mean changes in body composition in all 3 training groups after 8-week training

Body composition	WBV (n = 10)			WBV+BFR (n = 9)			WBV+HYP (n = 10)		
	Pre-test	Post-test	% change	Pre-test	Post-test	% change	Pre-test	Post-test	% change
Weight (kg)	83.99±25.49	83.48±24.43	-0.60	82.98±13.37	83.40±13.62	0.50	83.56±15.39	83.91±14.46	0.42
BMI (kg/m^2)	27.53±8.76	27.36±8.32	-0.62	28.48±3.39	28.60±3.29	0.41	27.08±4.81	27.16±4.40	0.27
Fat-Free mass (kg)	64.77±8.05	65.40±9.24	0.98	61.69±8.35	62.38±8.27	1.11	61.20±2.57	61.85±2.70	1.06
Fat mass (%)	22.78±10.21	22.75±9.14	-0.11	26.90±3.84	26.63±3.39	-1.01	25.55±8.32	25.25±9.29	-1.17
Skeletal muscle mass (kg)	31.84±5.29	32.26±5.62	1.29	31.76±4.71	32.06±4.66	0.94	30.18±2.57	31.05±2.62	2.90*
Skeletal muscle mass of right leg (kg)	7.17±1.51	7.30±1.60	1.71	6.22±0.71	6.32±0.60	1.67	6.38±0.35	6.56±0.35	2.82*
Skeletal muscle mass of left leg (kg)	6.92±1.43	7.02±1.62	1.33	6.18±0.68	6.28±0.60	1.68	6.62±0.67	6.74±0.63	1.88
Visceral adipose tissue (L)	3.51±3.94	3.27±3.01	-6.91	3.60±1.04	3.39±1.17	-5.99	3.03±1.50	2.79±1.19	-8.02

Description: *Significant $p<0.05$ (pre vs post)

Table 3. Mean changes in physical performance in all 3 training groups after 8-week training.

Variables	WBV (n = 10)			WBV+BFR (n = 9)			WBV+HYP (n = 10)		
	Pre-test	Post-test	% change	Pre-test	Post-test	% change	Pre-test	Post-test	% change
Flexibility									
Sit and reach test (cm)	18.73±6.29	20.20±5.85	7.83	14.22±7.28	15.52±7.03	9.14	13.13±4.46	14.45±4.25	10.03
Back extension test (cm)	34.12±5.91	36.75±7.52	7.72	33.09±6.36	36.09±6.27	9.07*	31.40±4.52	34.65±2.89	10.35*
Muscular strength									
Leg strength (kg/body weight)	1.56±0.42	1.71±0.42	9.15	1.35±0.25	1.55±0.39	15.02*	1.51±0.45	1.86±0.58	22.84*
Maximum strength (1RM)									
Leg press (kg)	107.05±14.42	125.97±17.09	17.68*	98.83±23.66	110.51±26.46	11.82*	113.13±19.64	145.15±16.77	28.31*†
Leg extension (kg)	164.57±17.60	174.43±23.37	5.99*	170.00±38.27	190.29±34.98	11.93*	160.50±24.51	186.50±38.17	16.20*
Leg curl (kg)	99.75±14.13	102.63±13.62	2.88	106.71±12.98	112.29±13.67	5.22*	106.20±23.76	120.60±20.44	13.56*†
Muscular endurance (Number of Reps at 40% 1RM)									
Leg extension (reps)	28.13±5.77	29.63±4.57	5.33	29.67±8.71	33.83±8.23	14.04*	26.60±7.09	34.20±7.33	28.57*†
Leg curl (reps)	28.14±5.79	31.86±5.55	13.20*	31.17±7.22	36.33±8.29	16.58*	32.00±7.07	43.00±9.80	34.38*†
Cardiorespiratory endurance									
VO_2max (ml/kg/min)	29.19±6.19	31.52±5.31	8.00	31.98±4.45	35.43±6.98	10.79*	29.34±8.53	34.59±9.10	17.88*
Muscular power									
Vertical jump (cm)	32.63±8.47	33.00±8.33	1.15	33.83±8.42	35.33±7.81	4.43	31.20±8.17	34.20±6.83	9.62*

Description: *Significant $p<0.05$ (pre vs post), †Significant $p<0.05$ (WBV vs WBV+HYP)

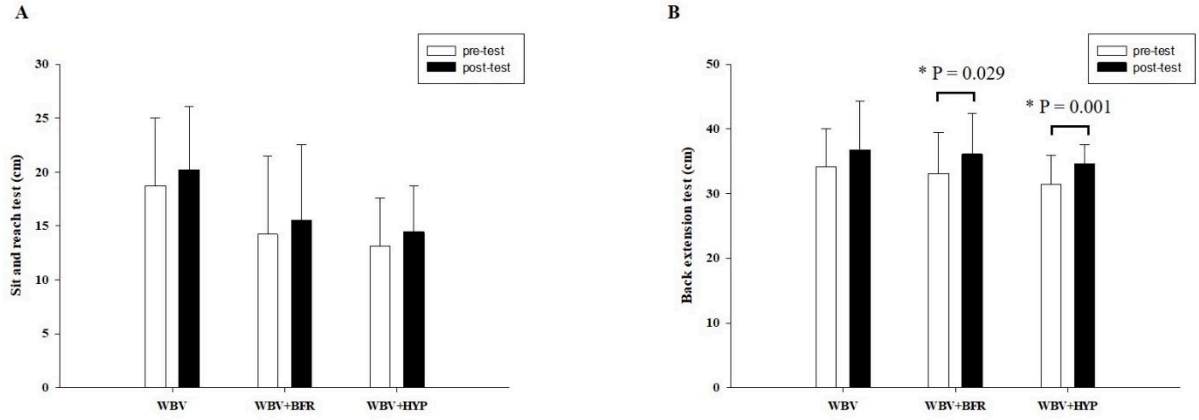

Fig. 2. Changes in flexibility (A; Sit and reach test and B; Back extension test) before and after 8-week of the training period. Values are present as mean ± SD. *Significant p<0.05 (pre vs post)

34.59 ± 9.10 ml/kg/min) and vertical jump (31.20 ± 8.17 cm and 34.20 ± 6.83 cm, baseline and post-intervention mean ± SD respectively) as a result of training (baseline to post-intervention) were not significantly different between groups (Fig. 4).

Discussion

This research investigated and compared the effects of whole-body vibration combined with blood flow restriction and hypoxic exposure. Previous studies found that training with a whole-body vibration machine can help improve muscle performance (Berner et al., 2020). Training with blood flow restriction can also help improve muscular strength (Cai et al., 2021). Training with hypoxic exposure, a new form of training, may also change the physiological mechanisms of training (Park et al., 2020). Therefore, this study was conducted to test the responses to the training among overweight adolescents.

In terms of body composition, any good changes or relatively obvious changes were not found. Only the WBV+HYP group had a significant increase in muscle mass and leg muscles (right side). Moreover, the fat mass and fat of the three groups did not change. However, a study by Park et al. (2020) showed that whole-body vibration training was effective in reducing body fat (Park et al., 2020). A research

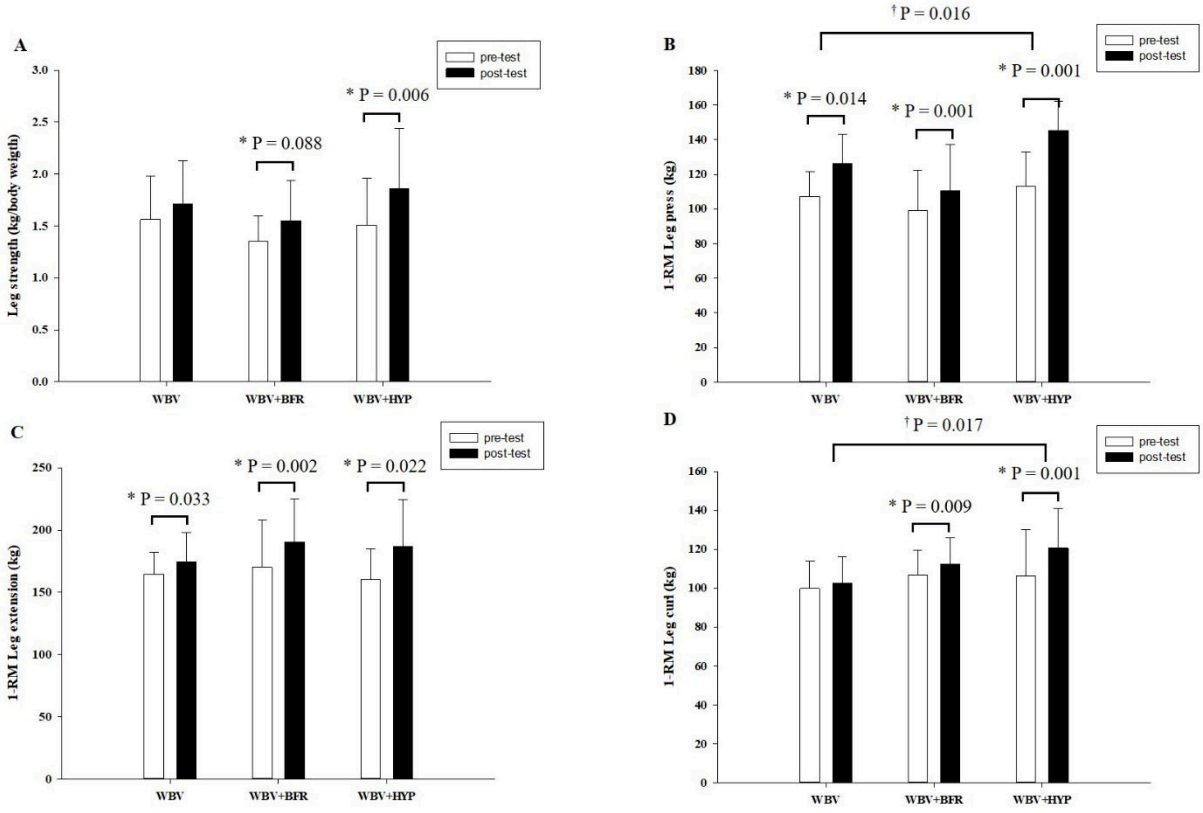

Fig. 3. Changes in muscular strength (A; Leg strength, B; 1-RM Leg press, C; 1-RM Leg extension and D; 1-RM Leg curl) before and after 8-week of the training period. Values are present as mean ± SD. *Significant p<0.05 (pre vs post), †Significant p<0.05 (WBV vs WBV+HYP)

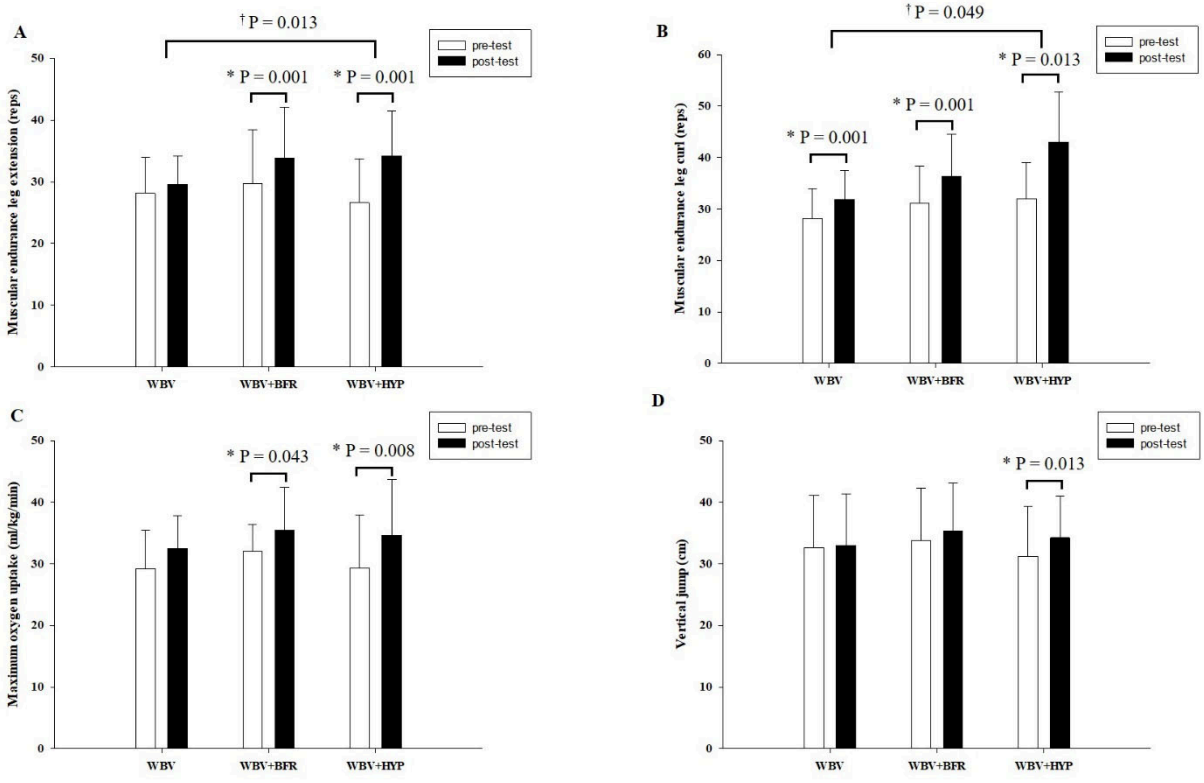

Fig. 4. Changes in muscular endurance, cardiorespiratory endurance and muscular power (A; Muscular endurance leg extension, B; Muscular endurance leg curl, C; Maximum oxygen uptake and D; Vertical jump) before and after 8-week of the training period. Values are present as mean ± SD. *Significant p<0.05 (pre vs post), †Significant p<0.05 (WBV vs WBV+HYP)

study by Vissers et al. (2010) also found that after training with a whole-body vibration machine for 6 months, body fat can be reduced (Vissers et al., 2010). Therefore, the following research hypothesis was developed: The duration of the experiment may affect the changes, which may take 10 weeks or more and the factors such as the subjects' diet and energy balance may also affect the changes. A study by Bellia et al. (2013) found significant changes in fat mass when whole body vibration training was combined with diet control. It may also be an important factor in increasing muscle mass although there was no significant change in overall muscle mass (Bellia et al., 2013). This is different from a study by Cai et al. (2021) which found that the BFR group had changes in leg muscle mass (Cai et al., 2021). However, the WBV+HYP group had significant changes in leg and right leg muscle mass. This is the factor that requires further study for hypoxic exposure or systemic hypoxia training.

Flexibility was significantly changed in the WBV+BFR and WBV+HYP groups in back extension, indicating that combined whole-body vibration training was effective in improving flexibility. In a study by Đorđević et al. (2022), an experiment was conducted among gymnasts and significant changes in flexibility was found (Đorđević et al., 2022). That is, the static squat position at 100° knee flexion can stimulate the muscles in thighs and core. The subjects must maintain a straight posture which may cause changes in strength and flexibility in the lumbar muscles.

Overall, changes in muscular strength in all three groups tended to improve. This is consistent with previous studies that blood flow restriction training was found to improve muscular strength (Cai et al., 2021; Cohen et al., 2022) or even whole-body vibration training alone can also increase muscular strength (Berner et al., 2020; Hegazy et al., 2021; Lai et al., 2021). This was especially true in the WBV+HYP group, where changes were similar to those in the BFR group. This may be caused by physiological changes during hypoxic training. Previous studies also found changes in muscular strength (Inness et al., 2016). As for muscular endurance, quite obvious changes were found in the WBV+BFR and WBV+HYP groups in accordance with the principles of stimulation and development during training (Plotkin et al., 2022). Most tests focused on muscle repetitions that measure endurance, and whole-body vibration training was shown to help improve this aspect of fitness (Cai et al., 2021; Kholvadia & Baard, 2012; Osawa et al., 2011). In addition, whole-body vibration combined with blood flow restriction or hypoxic exposure may help confirm that blood flow and oxygen restriction affect muscle response (Jessee et al., 2018; Kacin & Strazar, 2011; Manimmanakorn et al., 2013) although the training is in the muscle contraction posture. It is also expected that if it is practiced with postures that include movement, it may result in increased muscle endurance.

Muscular power was only changed in the WBV+HYP group. It is consistent with a study by Inness et al. (2016) where changes in maximum muscular power were found in heavy resistance training in hypoxia (Inness et al., 2016). However, there are few studies on the muscular power of whole-body vibration training. In this research, whole-body vibration training may not be the most effective way to develop muscular power. Further study is required.

In the WBV+BFR and WBV+HYP groups, significant changes in VO_2max occurred after 8 weeks of training. Previous studies showed that hypoxic exposure can help improve VO_2max (Deldicque, 2022; Westmacott et al., 2022), and it can be clearly seen when FiO_2 is lower than 13.8%. In terms of physiological factors, vascular endothelial growth factor (VEGF) is stimulated by hypoxia (Downs et al., 2014; Shimizu et al., 2016), and it may be the factor that can increase the ability to manage and control oxygen levels during exercise.

In this research, the following research gaps and limitations can be found. The basic factors of the subjects, including age, gender and experience with exercise training may affect the level of change. In addition, a longer period of time (12 weeks to 6 months) is required. Moreover, frequency of training and the intensity of hypoxia may result in more pronounced changes. Suitability and safety between the training programs and the subjects should be considered. Also, other factors that can be controlled or monitored, such as diet, stress, and rest may help identify the cause of changes.

Conclusions

Whole-body vibration combined with blood flow restriction and hypoxic exposure were effective in improving body composition and physical fitness. In particular, the group that combined training with hypoxic exposure showed good changes in maximum muscular strength in leg press and leg curl, and muscular endurance in leg extension and leg curl when compared to the group trained with the whole-body vibration machine alone. This is useful in choosing the form of training that can help develop various aspects of physical fitness for beginners or people who are unable to choose the type of exercise. The combination of whole-body vibration training with blood flow restriction and hypoxic exposure can effectively improve physical fitness. It can also be adjusted according to convenience and suitability for each individual. It is a guideline for preventing, treating, and promoting health among overweight adolescents.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Вплив біомеханічної стимуляції в поєднанні з обмеженням кровотоку та системною гіпоксією на композицію тіла та фізичну продуктивність студентів університету з надмірною вагою

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 10 с., 3 табл., 4 рис., 33 джерела.

Мета дослідження. У цьому дослідженні вивчався вплив біомеханічної стимуляції (БМС) у поєднанні з обмеженням кровотоку (ОК) та гіпоксичним впливом (ГВ) на композицію тіла та фізичну продуктивність студентів університету з надмірною вагою.

Матеріали та методи. Двадцять дев'ять студентів чоловічої статі з надмірною вагою були розподілені на 3 групи: 1) біомеханічна стимуляція (БМС), 2) біомеханічна стимуляція плюс обмеження кровотоку (БМС+ОК, 60% оклюзійного тиску) і 3) біомеханічна стимуляція плюс гипоксичний вплив (БМС+ГВ, FiO_2 = 15,8%). Тренування включало 10 сеансів виконання інтервальних фізичних вправ на основі БМС (частота 30-35 Гц і висока амплітуда) по 20 хв/день і 3 дні на тиждень. Показники композиції тіла разом з фізичною продуктивністю вимірювалися до (2-3 дні) і після (2-3 дні) 8-тижневого періоду тренувань.

Результати. Результати проведеного дослідження були наступними: після тренування показники максимальної сили (1RM) у жимі ногами та згинанні ніг значно зросли у досліджуваній групі, що проходила процедури БМС +ГВ (28,31%,

p = 0,016 та 13,56%, p = 0,017) порівняно з групою, де була проведена БМС (17,68% та 2,88), відповідно. Аналогічно, у учасників досліджуваної групи, що проходила процедури БМС+ГВ спостерігалося значне збільшення показників м'язової витривалості у розгинанні та згинанні ніг (28,57%, p = 0,013 та 34,38%, p = 0,049) порівняно з групою, в якої була застосована БМС (5,33% та 13,20%), відповідно.

Висновки. Біомеханічна стимуляція в поєднанні з обмеженням кровотоку та гіпоксичним впливом показали свою ефективність у покращенні композиції тіла та фізичної підготовленості. Проведення процедури також можна регулювати відповідно до вимог та індивідуальних особливостей кожної особи. Дана методика є керівним принципом для профілактики, лікування та підтримки здорового способу життя серед підлітків з надмірною вагою.

Ключові слова: біомеханічна стимуляція, обмеження кровотоку, системна гіпоксія, композиція тіла, фізична продуктивність, надмірна вага

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Interaction of Skating Agility Tests and Postural Stability in Hockey Players

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Abstract

Study purpose. In this work, we point out the interaction of complex postural stability (CPS) and skating agility tests among pupils in the hockey club HK Nové Zámky. We determined postural stability using the SEBT and agility with skating tests. We expected a significant interaction between performance in skating agility tests and CPS for both standing legs, which was most closely identified with the eight-item SEBT test.

Materials and methods. The level of CPS was characterized by descriptive statistics. Laterality between right and left standing leg was assessed by t-test and Cohen's "d". The relationships between CPS and skating agility tests were determined by Pearson's correlation coefficient "r". Predictors were selected by stepwise regression. Statistical significance of differences and relationships was assessed at the 5% significance level.

Results. The results showed no differences in the laterality of the CPS between the right and left standing leg. Correlation analysis demonstrated the interactions of the left and right standing leg with all skating agility tests. Stepwise regression was used to select the tests that were most identified with the performance on the eight-item SEBT test in terms of their skating expression. The Illinois test has the most significant informational power for CPS.

Conclusions. The presence of positive interactions between skating agility and CPS in hockey players point to the importance of a balanced and stable stance of both legs in all directions. The perfect balance and stability of hockey players eliminates the fluctuations caused by skating movement in all directions and facilitates their execution without major changes in dynamic performance. The chance of shortening the activation time of the muscle chains involved in the technique of performing the test also increases significantly, or in the very structure of technique – the economics of ice hockey players' skating.

Keywords: hockey, postural stability, skating agility, interactions.

Introduction

A high ability to maintain postural stability means keeping the vertical projection of our center of gravity at the basic support level; it is essential in sports (Andreeva et al., 2021).

Hockey is included in sports games that require the comprehensive readiness of the players of the entire team. Players are able to produce high skating speed during the game, but with sudden changes of direction (Alpini et al. 2008; Antara et al. 2023). One of the inseparable parts of preparedness is precisely postural stability.

In the literature, postural stability is characterized by maintaining balance and control over your body during movement, thanks to which we are able to adequately react to the situation during the game, such as: contact with an opponent (Bournival et al. 2023).

The precise definition of the term "agility" was brought to us by Sheppard et al. (2014), who describe it in the literature as the athlete's ability to change the speed and direction of movement quickly and accurately during the reaction to a specific stimulus from the external environment.

Young et al. (2015) include situations in sports games as specific stimuli. These stimuli may vary in terms of intensity and spatiotemporal conditions.

However, Plisk (2008) states that when performing any agility test, it is due to the non-constant speed while covering the distance.

In the studies, we are able to find models containing specific determinants according to the authors. Jeffreys (2011) lists perceptual limitations (ability to focus, attention), cognitive limitations (situation recognition, concentration, problem-solving ability), physical limitations (strength, muscle fiber typology) and motor limitations as determinants. For comparison, Sheppard et al. (2014) state that agility is determined by perception and decision-making (knowledge of the given situation), change of direction and speed, technique (acceleration/deceleration of movement, body posture), sprint speed, muscle properties of the lower limbs (leg strength, reaction speed, muscle imbalance right/left leg) and anthropometry.

Tests focused on speed, maximum strength or endurance are known in the literature. Compared to testing motor skills such as "agility", they remain in the background even in current literature (Hojka et al., 2016; Bakhsis, 2023).

In the sports performance of hockey players, postural stability and agility is a directly limiting factor because correct postural stability significantly affects the technique of hockey players and their ability to perform correct movements. Players with a high level of postural stability are better able to maintain the correct position of the body during skating, shooting or blocking a shot.

Materials and methods

Study participants

The research was carried out on a group of hockey players in the category of younger pupils from Slovakia (n = 20).

Study organization

Dynamic postural stability was determined using the eight-position Star Excursion Balance Test (SEBT) and movement performance in skating agility tests 6x9 m, 30 m, 36 m forward, 36 m backward, Illinois test, Circle forward, Circle backward and Square.

The SEBT test was performed in the directions Posterior, Posteromedial, Medial, Anteriomedial, Anterior, Anteriolateral, Lateral, Posterolateral for the right and left standing leg (Figure 1).

The output measurements for the right and left training leg are assessed from the point of view of the average value from 3 attempts (cm), the maximum measured value (cm), and the relative value (Relative – normalized distance in each direction (%) = Average distance in each direction / length lower limb*100). Complex postural stability (KPS) in both legs = average of average values from 3 SEBT attempts (composite scores) (Garret et al. 2012; Calatayud et al. 2017).

Statistical analysis

The DPS level and hockey players' sports performance was characterized by descriptive statistics (M, SD, Max, Min). Statistical and material significance of differences was assessed by t-test and Cohen's "d". The relationships between KPS and skating agility tests were determined by Pearson's correlation coefficient "r". Skating agility tests were selected by stepwise regression, which showed the highest closeness with KPS. For the models, we present the stepwise regression parameters (R Square, ANOVA parameters F, p value, partial share Beta*r). Statistical significance of differences and relationships was assessed at the 5% and 1% significance levels.

Results

By comparing the complex postural stability in the right (RSL) and left standing leg (LSL), we found no differences in laterality (tables 1 and 2) in average values $t_{(19)} = 0.959$, $p = 0.350$, $d = 0.166$, maximum values $t_{(19)} = 1.365$, $p = 0.188$, $d = 0.356$ and not even for relative values $t_{(19)} = 0.959$, $p = 0.350$, $d = 0.166$.

Correlation analysis showed interactions of KPS in the left and right standing leg with all skating agility tests ($p<0.05$). The 36 m backward skating test did not uniquely show significant relationships (p = n.s.) with KPS on the right standing leg (Tables 3 and 4). We do not report the calculated correlations of the relative parameters of the KPS due to the same values as the average ones.

A high correlation tightness (r = 0.70-0.90) with KPS was demonstrated by the Illinois skating test (LSL & RSL $p<0.01$), 36 m forward (LSL & RSL $p<0.01$) and 6x9m (LSL $p< 0.01$). Low tightness (r = 0.30-0.50) was observed in the 36 m backward skating test (LSL $p<0.05$; RSL $p<0.10$).

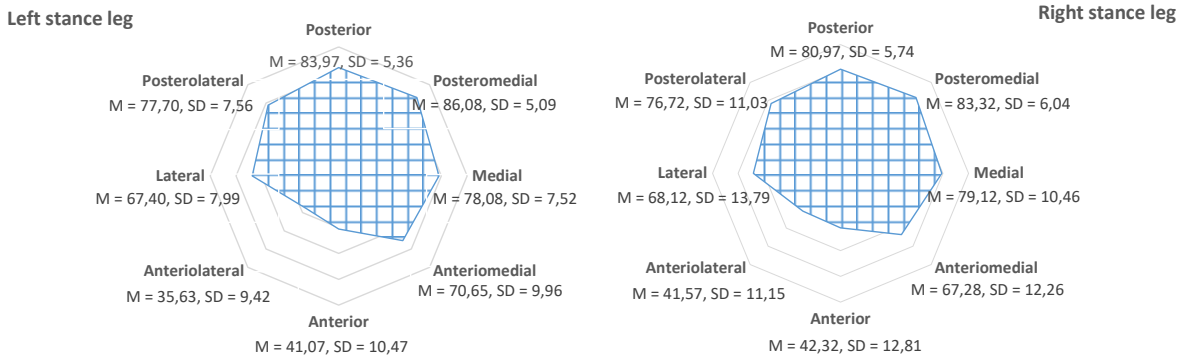

Fig. 1. Level of postural stability of hockey players on the right and left standing leg tested with the eight-way SEBT test

Table 1. Level of complex dynamic postural stability (DPS) and performance in skating agility tests

Variables		M	SD	Max	Min
Left stance leg	Average (cm)	67.57	7.07	79.62	52.00
	Maximum (cm)	69.61	7.26	81.62	53.37
	Relatively (cm)	77.67	8.13	91.52	59.77
Right stance leg	Average (cm)	67.43	9.52	86.25	44.62
	Maximum (cm)	69.63	9.54	89.37	46.75
	Relatively (cm)	77.50	10.94	99.13	51.29
Skating agility	6×9 m (s)	18.89	2.53	27.01	27.01
	30 m (s)	4.84	0.65	6.30	4.10
	36 m forward (s)	6.78	0.79	8.21	5.38
	36 m back (s)	9.25	1.22	13.40	7.59
	Ilinois test (s)	20.0	2.45	24.12	16.48
	Circle forward (s)	29.6	4.15	40.43	25.31
	Circle back (s)	30.9	4.62	44.21	26.04
	Square (s)	19.20	3.72	29.01	15.25

Table 2. Differences of complex DPS between left and right standing leg

Variables	Diferencies Left and Right leg			
	d	t	p	d
Average (cm)	0.148	0.164	0.871	0.018
Maximum (cm)	0.025	0.028	0.978	0.003
Relatively (cm)	0.170	0.164	0.871	0.018

Labels: M - average, SD - standard deviation, Max - maximum, Min - minimum, d - difference of means, t - value, p - value, Cohen's "d"

Table 3. Correlations between KPS in the right and left standing leg with skating agility tests (Pearson's correlation coefficient "r" and p value) - average values

Variables		Average value			
		Left stance leg		Right stance leg	
		r	p	r	p
Skating agility	6×9 m	-0.769	0.000	-0.653	0.002
	30 m	-0.563	0.009	-0.645	0.002
	36 m forward	-0.762	0.000	-0.809	0.000
	36 m back	-0.475	0.033	-0.405	0.075
	Ilinois test	-0.873	0.000	-0.858	0.000
	Circle forward	-0.564	0.009	-0.507	0.022
	Circle back	-0.574	0.007	-0.507	0.021
	Square	-0.628	0.003	-0.578	0.007

The remaining skating tests 30 m, Circle forward & back and Square showed moderate correlations (r = 0.50-0.70, p<0.01).

By stepwise regression, two tests were selected, most identified with the performance of the eight-way SEBT test due to their skating expression (Table 5). The Illinois test (left leg 58.09% – 76.24% and right leg 73.63% – 73.92%) has the greatest information power for KPS before the 6x9m skating test (left leg 25.10%). The remaining skating tests were not selected despite the high tightness. All regression models showed statistical significance (p<0.01) and a high degree of tightness, respectively. dependence (R^2 = 73.62%-83.19%).

Table 4. Correlations between KPS in the right and left standing leg with skating agility tests (Pearson's correlation coefficient "r" and p value) – maximum values

Variables		Max value			
		Left stance leg		Right stance leg	
		r	p	r	p
Skating agility	6×9 m	-0.785	0.000	-0.669	0.001
	30 m	-0.565	0.009	-0.489	0.027
	36 m forward	-0.758	0.000	-0.812	0.000
	36 m back	-0.482	0.030	-0.423	0.062
	Ilinois test	-0.883	0.000	-0.860	0.000
	Circle forward	-0.563	0.009	-0.527	0.016
	Circle back	-0.573	0.008	-0.530	0.015
	Square	-0.639	0.002	-0.511	0.020

Discussion

Alpini et al. (2008), Bakhsis (2023) points out that ice hockey players can produce high skating speed during the game and the situations are characterized by sudden accelerations, decelerations and changes of direction.

Recorded positive interactions between agility tests on ice and PS in hockey players are supported by the research of Behm et al. (2005) because hockey skating performance is significantly correlated with balance and sprint tests, which points us to the important role that postural stability plays in skating speed in players.

In the databases, we find studies that investigatied the differences between hockey players' left and right legs or compared the performances in dynamic-static balance of ice hockey players and ordinary individuals (Hansen et al., 2016; Arboix-Alió & Aguilera-Castells, 2021; Kara et al., 2022).

Hansen et al. (2016) investigated the differences between the left and right foot in a group of hockey players (n=28). A lateral jump on a force platform was used as a test to compare both legs. The task of the probands was to stabilize the movement. The authors concluded they did not notice statistically significant differences between the left and right legs when performing the test.

The authors Arboix-Alió & Aguilera-Castells (2021) similarly investigated the differences between left and right legs in hockey players (n= 25). The Triple Hop Test was performed with both legs. The results showed that the recorded left and right leg differences are not statistically significant.

The results of both authors mentioned above (Hansen et al. 2016; Arboix-Alió & Aguilera-Castells, 2021) fully support our achieved results.

Comparative testing of dynamic-static balance between ice hockey players (n=37) and ordinary individuals (n=37) was carried out in a study by Kara et al. (2022). The

Table 5. Step regression parameters of selected skating agility tests to KPS for the right and left standing leg

Variables		Average value		Max value		Relatively value	
		Left	Right	Left	Right	Left	Right
6×9 m	Beta*r			0.251			
	r			-0.785			
Ilinois test	Beta*r	0.7493	0.7363	0.5809	0.7392	0.7624	0.7362
	r	-0.858	-0.858	-0.884	-0.860	-0.873	-0.858
ANOVA	R^2	0.7624	0.7363	0.8319	0.7392	0.7624	0.7362
	F	57.77	50.27	42.05	51.02	57.76	50.24
	p	0.00	0.00	0.00	0.000	0.00	0.00

Labels: R^2 - Square, Pearson coefficient "r", ANOVA parameters F, p value, partial proportion Beta*r

experimental group was made up of professional hockey players and the control group was made up of men with no sports activity in the past. The authors report results without significant differences between the experimental and control groups in dynamic-static balance tests. We assumed significant differences between the groups, as hockey players regularly implement a training process with a focus on dynamic-static balance.

Chauhan et al. (2023) point to the finding that a training process with a focus on stability, which is regularly implemented, leads to better postural stability and dexterity of the players during the game. However, the recorded performance in individual tests of postural stability is often influenced by factors such as: heartbeat or respiratory muscle activity (Zemková, 2004).

Postural stability is related not only to the optimal performance of the athlete, but also to the sustainability of the player in the sport in the long term. Players with balanced and adequately strengthened muscle fibers are not as prone to back injuries, joints or other problems related to incorrect posture (Sahin, 2020).

For coaches, we see regular testing of their players in static and dynamic positions in the future, where they can evaluate the performance level of hockey players and then compare the results with other clubs.

Conclusion

The topic of complex postural stability is gradually becoming one of the basic building blocks of properly implemented sports performance. Players with a high level of complex postural stability can better control their body during the game, properly manage tense situations that come with the match and may be less prone to possible injuries.

The positive interactions we recorded between skating agility tests and KPS prove to us how important it is for hockey players to have a stable and balanced stance on both legs in all directions of movement. A high level of stability in hockey players can largely eliminate fluctuations that occur during skating and, on the contrary, facilitate their performance.

The identification of the agility test of Illinois with the eight-way test of complex postural stability shows us their mutual predictive possibilities, which could be the subject of interest and implementation of further research in the future.

For this reason, training focusing on postural stability should not be neglected, but on the contrary, should become a regularly implemented and inseparable part of every hockey player. Hockey clubs should include the chosen program in their training units.

Conflict of interest

The authors declare that they have no conflict of interest.

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Взаємозв'язок тестів на спритність при пересуванні на ковзанах та показники постуральної стійкості у хокеїстів

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 6 с., 5 табл., 1 рис., 19 джерел.

Мета дослідження. У цій роботі ми вказуємо на взаємозв'язок комплексної постуральної стійкості (КПС) та тестів на спритність при пересуванні на ковзанах у вихованців хокейного клубу ХК "Nové Zámky". Ми визначали постуральну стійкість за допомогою тесту SEBT (балансувальний тест «рух траєкторією зірки») і тестів на спритність при катанні на ковзанах. Ми очікували на значний взаємозв'язок між показниками тестів на спритність при пересуванні на ковзанах та КПС для обох ніг в положенні стоячи, що було найбільш тісно пов'язано з тестом SEBT, що складається з восьми позицій.

Матеріали та методи. Рівень КПС характеризували за допомогою методів описової статистики. Латеральність між правою та лівою ногою в положенні стоячи, оцінювали за допомогою t-критерію та методикою d Коена. Взаємозв'язок між КПС та тестами на спритність при пересуванні на ковзанах визначали за допомогою коефіцієнта кореляції Пірсона (позначають "r"). Предиктори були обрані за допомогою покрокової регресії. Статистичну значущість відмінностей і взаємозв'язків оцінювали на 5% рівні значущості.

Результати. Результати не показали відмінностей у латеральності КПС між правою та лівою ногою в положенні стоячи. Кореляційний аналіз продемонстрував взаємозв'язок лівої та правої ноги в положенні стоячи з усіма тестами на спритність при пересуванні на ковзанах. Покрокова регресія була використана для відбору тестів, які найбільше ідентифікуються з показниками тесту SEBT, що складається з восьми позицій, з точки зору їх вираженості при пересуванні на ковзанах. Іллінойський тест має найбільш значну інформативність для КПС.

Висновки. Наявність позитивних взаємозв'язків між спритністю пересування на ковзанах та КПС у хокеїстів вказує на важливість збалансованого та стабільного положення обох ніг у всіх напрямках. Оптимальний баланс і стабільність хокеїстів усуває коливання, викликані рухами під час пересування на ковзанах у всіх напрямках, і полегшує їх виконання

без значних змін у динамічних показниках. Також значно збільшується шанс скорочення часу активації м'язових ланцюгів, задіяних в техніці виконання тесту, або в самій структурі техніки – економічність катання хокеїстів на ковзанах.

Ключові слова: хокей, постуральна стійкість, спритність при пересуванні на ковзанах, взаємозв'язки.

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Using Support Vector Regression Kernel Models for Cricket Performance Prediction in the Womens Premier League 2024

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Abstract

Background. The interest in women's premier league cricket has caused the need for advanced analytics to understand the multifaceted dynamics of the sport.

Study Purpose. This study aimed to contribute to sports analytics by assessing the efficacy of Support Vector Regression (SVR) kernel models in predicting the most valuable player. Such research methods as ANOVA, Bessel function, and Inverse MultiQuadratic kernel application have been deliberately chosen for their diverse mathematical approaches, aligning with the nuanced intricacies of women's premier league cricket.

Materials and methods. Player performance was analyzed by using the following study methods: ANOVA, Bessel function and Inverse MultiQuadratic kernel application. The data, sourced from espncricinfo.com and the International Cricket Council, includes essential metrics for five teams. Rigorous preprocessing techniques, such as imputation and outlier removal, enhance data reliability, ensuring robust predictive models.

Results. The application of the Inverse MultiQuadratic kernel exhibits exceptional predictive performance, surpassing ANOVA and Bessel function models. The kernel's radial basis function proves effective in capturing the intricate dynamics of women's premier league cricket. The findings underscore the suitability of kernel method for predicting standout performers in the Women's Premier League 2024 season.

Conclusions. The study revealed the dynamic interplay between sports analytics and machine learning in women's premier league cricket. The application of the Inverse MultiQuadratic kernel stands out as the most effective model, providing key insights into player predictions. This emphasizes the continual integration of advanced analytical techniques to enhance our understanding of the evolving landscape of women's premier league cricket. As the sport gains prominence on the global stage, such analytical endeavors become imperative for strategic decision-making and sustained growth.

Keywords: women's cricket, support vector regression, machine learning, comparative analysis, performance prediction.

Introduction

The realm of women's premier league cricket has been experiencing unprecedented growth, attracting heightened attention from enthusiasts and stakeholders alike. In response to this surge, the significance of employing advanced predictive modeling techniques cannot be overstated (Kapadia et al., 2022). This research endeavors to explore the application of Support Vector Regression (SVR) with distinct kernel models, namely ANOVA, Bessel function, and Inverse MultiQuadratic, to predict the player's performance of women's premier league cricket in the upcoming 2024 season (Sumathi et al., 2023; Aburas et al., 2018). Cricket, as a sport, is influenced by a multitude of factors, ranging from individual player form to team dynamics and external conditions. Leveraging sophisticated analytics and machine learning methodologies holds the potential to unravel the intricate relationships within these factors, surpassing

traditional statistical approaches (Subburaj et al., 2023; Passi and Pandey, 2018a). This study seeks to contribute to the evolving field of sports analytics by examining the effectiveness of different SVR kernel models in forecasting the player's performance of women's cricket league (Passi and Pandey, 2018b; Bunker and Thabtah, 2019).

Support Vector Regression and Kernel Models. SVR is grounded in finding an optimal hyperplane that maximizes the margin between data points, accommodating a controlled margin of error to handle intricate, non-linear relationships within a dataset (Vetukuri et al., 2019). The core of SVR's efficacy lies in its utilization of kernel functions to map input data into higher-dimensional spaces. These kernels are pivotal in transforming input features, a choice that significantly impacts SVR's performance and is crucial for predictive modeling (Dogan and Birant, 2021; Abebe et al., 2020).

The ANOVA kernel, derived from Analysis of Variance, offers a distinctive approach to SVR by emphasizing the capture of variance in datasets. This kernel excels when intricate variations within the data play a pivotal role. By prioritizing the discernment of nuanced variances, the ANOVA kernel enhances SVR's ability to identify subtle patterns within the intricate dynamics of women's premier league cricket performances (Gu et al., 2023). Introducing an oscillatory behavior, the Bessel function kernel excels at capturing periodic patterns and cyclic variations in datasets. In the context of cricket performance predictions, where team dynamics may exhibit periodic fluctuations, the Bessel function kernel becomes a valuable mathematical tool. Its ability to resonate with cyclical patterns contributes to a holistic understanding of factors influencing women's cricket player's performances (Gu et al., 2023; Saikia, 2020). The Inverse MultiQuadratic kernel introduces a radial basis function, offering a unique perspective on the relationship between input features. By incorporating the inverse of the Euclidean distance between data points, this kernel underscores the significance of proximity in predictive modeling. In the domain of women's premier league cricket, where team dynamics and interactions significantly impact performance, the kernel's focus on proximity adds a layer of sensitivity to the SVR model (Gu et al., 2023; Wickramasinghe, 2014).

This research's intentional focus on women's premier league cricket underscores the importance of gender-inclusive sports research (Subburaj et al., 2023). As women's cricket continues to ascend on the global stage, understanding and predicting team dynamics become imperative for various stakeholders (Passi and Pandey, 2018b). These include team management making strategic decisions, sponsors assessing investment opportunities, and fans engaging in the sport. Through our comparative analysis, we aim to provide a nuanced understanding of the strengths and weaknesses of distinct SVR kernel models concerning predicting the most valuable player in women's premier league cricket 2024 (Bunker and Thabtah, 2019; Wickramasinghe, 2014). The selected kernels for this study, ANOVA, Bessel function, and Inverse MultiQuadratic, represent diverse mathematical approaches. ANOVA, emphasizing variance analysis, aims to capture nuanced variations in player's performances. Bessel function, known for its oscillatory behavior, brings a unique perspective to the analysis (Hudnurkar & Rayavarapu, 2022). The Inverse MultiQuadratic kernel introduces a radial basis function that may enhance predictive capabilities. The objective in comparing these kernels is to identify the model that best aligns with the complex dynamics inherent in women's premier league cricket (Van Eetvelde et al., 2021; Anam et al., 2021).

The purpose of the research. The Support Vector Regression (SVR) with ANOVA, Bessel function, and Inverse MultiQuadratic kernels to predict player performance in the Women's Premier League Cricket 2024 season.

Materials and Methods

Study Participants

The dataset is meticulously curated from two reliable sources: espncricinfo.com and the official website of the International Cricket Council (ICC). The dataset metrics for five teams and a total of 90 players participating in the WPL, including the number of matches played, batting averages, bowling averages, catches taken, and the T20 status of the 18 players in each squad, as shown in Figure 1 (International Cricket Council; ESPNcricinfo; Women's Premier League).

Matches	Batting_Avg	Bowling_Avg	Catches	Performance_Prediction
44	16.529382	29.409980	7.535972	43.356918
78	7.888586	23.961124	17.246971	75.019049
30	7.841652	20.171912	5.598902	56.491503
90	8.529467	24.112106	13.446212	69.412674
94	7.768144	25.286781	29.203114	55.396902
25	43.827092	1.262447	11.341412	55.140026

Fig. 1. Sample Dataset

Study organization

This investigation aims to predict the most valuable player of the upcoming Women's Premier League (WPL) 2024 season, focusing on essential performance metrics using three different SVR kernel models such as ANOVA, Bessel function, and Inverse MultiQuadratic. Data preprocessing to address missing values is fundamental to the reliability of predictive models. Robust imputation methods, such as mean or median imputation, are employed to fill in missing values. Additionally, data integrity checks are performed to identify and rectify any anomalies in the dataset. Identifying and removing outliers is critical for refining the dataset. Outliers can distort model training, and their removal enhances the robustness and generalization capabilities of the SVR models (Subburaj et al., 2023).

The data splitting adheres to a well-established principle, allocating 80% of the acquired dataset for training the Support Vector Regression (SVR) models, while reserving the remaining 20% for rigorous testing and evaluation. This meticulous division ensures a robust and comprehensive training phase, allowing the SVR models to glean intricate patterns and relationships from the majority of the data. Subsequently, the earmarked 20% functions as an independent dataset, remaining untouched during the training process, thereby facilitating an unbiased assessment of the models' predictive capabilities (Kapadia et al., 2022; Men,

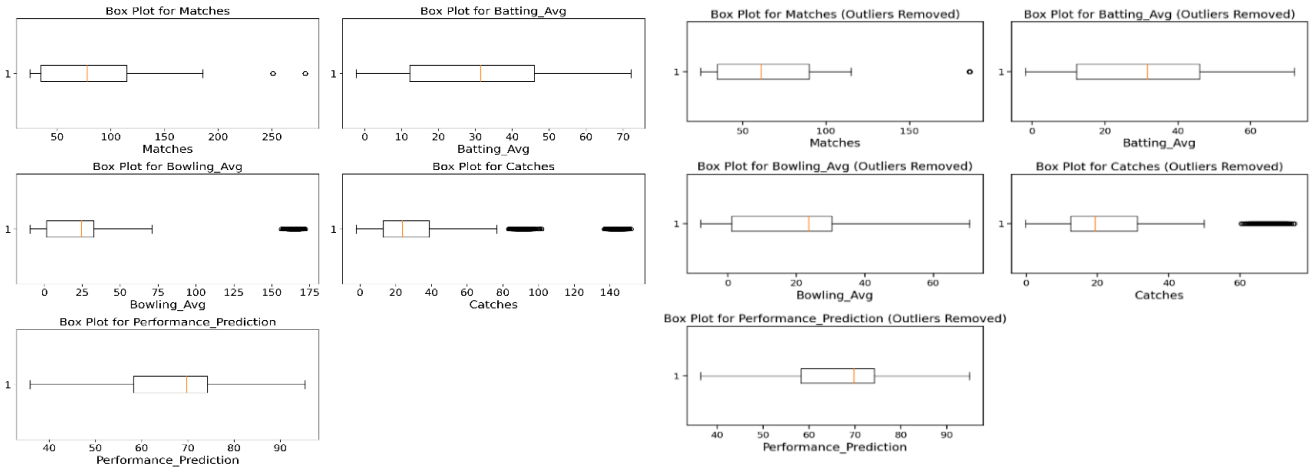

Fig. 2. In the presence of outliers, the dataset is graphically displayed as a boxplot (A), and outliers were eliminated as shown in (B)

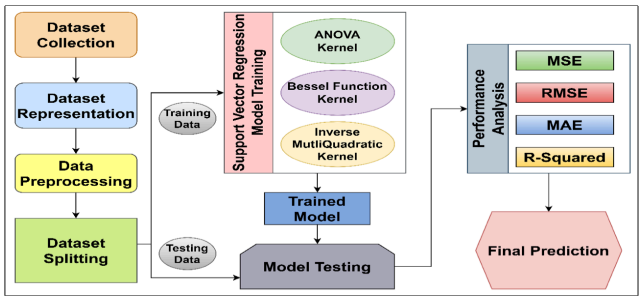

Fig. 3. Methodological process overview

2022). The training process involved the application of three distinct kernels - ANOVA Kernel, Bessel Function Kernel and Inverse MultiQuadratic Kernel. Parameters were fine-tuned through methods like grid search, ensuring optimal model performance. Testing involved making predictions on the independent dataset, and the models' effectiveness was evaluated using metrics such as Mean Squared Error and R-squared (Sanjaykumar et al., 2023). The ultimate aim is to contribute to the creation of reliable and precise predictive models capable of accurately forecasting the performance of women's premier league cricket players in the anticipated 2024 season.

Statistical analysis

Mean Squared Error (MSE) calculates the average squared difference between predicted (Apredict) and actual (Aactual) values, while Root Mean Squared Error (RMSE) is its square root. Mean Absolute Error (MAE) measures the average absolute difference. R-Squared (R^2) evaluates predictive accuracy by comparing actual and predicted values to the mean.

$$\text{Mean Squared Error (MSE)} = \frac{1}{x} * \sum(A_{predict} - A_{actual})^2$$

$$\text{Root Mean Squared Error (RMSE)} = \sqrt{MSE}$$

$$\text{Mean Absolute Error (MAE)} = \frac{1}{x} * \sum(A_{predict} - A_{actual})$$

$$\text{R-Squared } (R^2) = 1 - \left[\frac{\sum(A_{actual} - A_{predict})^2}{\sum(A_{actual} - A_{mean})^2}\right]$$

In the given equation, Aactual signifies observed performance values, Apredict represents predicted performance, Amean stands for the mean of actual performance values, and x denotes the number of data points (Sanjaykumar et al., 2023; Rajendiran and Rethnaraj, 2023).

Results

The research study unfold the outcomes on predicting the most valuable player in the upcoming Women's Premier League (WPL) 2024 season. The research focus lies on leveraging Support Vector Regression (SVR) with distinctive kernel models – ANOVA, Bessel function, and Inverse MultiQuadratic. This segment serves as an exclusive platform to present our analyses and engage in a comprehensive discussion, dissecting the performance of each SVR kernel model in forecasting women's premier league cricket.

Comparative analysis

The Comparative Analysis section unfolds a detailed assessment of the diverse Support Vector Regression (SVR) kernel types ANOVA, Bessel function, and Inverse MultiQuadratic based on essential metrics such as Mean Squared Error (MSE), Root Mean Squared Error (RMSE), Mean Absolute Error (MAE) and R-Squared (R^2) Table 1. These metrics serve as pivotal indicators in gauging the precision and efficacy of each kernel in predicting the most valuable player for the Women's Premier League 2024 season. The ensuing discourse meticulously explores the distinctive characteristics of each kernel, presenting unique insights into their individual strengths and areas where refinement may enhance predictive capabilities.

The Support Vector Regression (SVR) kernel types ANOVA, Bessel function, and Inverse MultiQuadratic reveals the distinct performance metrics crucial for assessing their predictive capabilities in the context of the Women's Premier League 2024 season. In analyzing the Mean Squared Error (MSE), the average squared disparity between predicted and actual values, it emerges as the most proficient

Table 1. Performance metrics of support vector regression with different kernelsTop of Form

Support Vector Regression – Kernel Type	Mean Squared Error (MSE)	Root Mean Squared Error (RMSE)	Mean Absolute Error (MAE)	R Squared (R^2)
ANOVA	20.1357	4.4872	8.0684	0.79386
Bessel function	18.2389	4.2707	7.1290	0.81563
Inverse MultiQuadratic	13.6294	3.6918	2.5639	0.86392

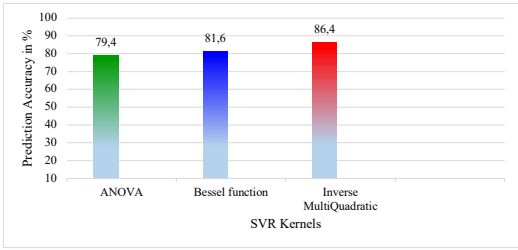

Fig. 4. Accuracy analysis of support vector regression with different kernels

with the lowest MSE of 13.6294. Root Mean Squared Error (RMSE), emphasizing prediction accuracy, echoes this trend, where it attains the smallest RMSE of 3.6918. Mean Absolute Error (MAE), indicating average absolute differences, further underscores Inverse MultiQuadratic's superiority with the smallest MAE of 2.5639. R-squared (R^2) gauging explanatory power, consistently position with the highest values, signifying its adeptness in capturing variance and making precise predictions (Table 1). In essence, these findings accentuate the exceptional predictive performance of the kernel in this comparative analysis (Figure 4).

Performance Prediction Based on Inverse MultiQuadratic kernel.

The application of the Inverse MultiQuadratic kernel in Support Vector Regression (SVR) emerges as a standout feature in our research, showcasing an impressive predictive accuracy of 86.4%. This surpasses the performance of other kernels, specifically ANOVA and Bessel function, in anticipating the most valuable player for the Women's Premier League 2024 season. This kernel, characterized by its radial basis function, proves to possess an exceptional capability to discern intricate patterns within the dataset, leading to heightened precision in performance predictions.

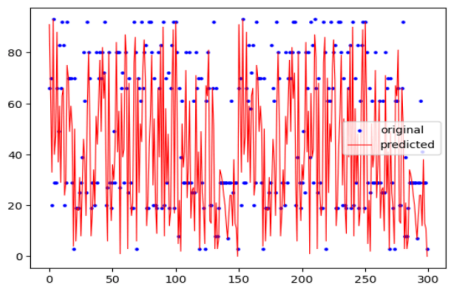

Fig. 5. Visualizing the performance prediction graph of the Inverse MultiQuadratic kernel model, the predicted values (donated in red) and actual value (represented in blue color) with slight deviation

Most Valuable Player prediction based on Inverse MultiQuadratic kernel.

The predictions based on the Inverse MultiQuadratic kernel for the most valuable player in the upcoming Women's Premier League (WPL) season 2024 reveal intriguing insights into the potential standout performers. Hayley Matthews emerges as a front-runner with a substantial prediction percentage of 84.1%, indicating a high likelihood of her securing the coveted title. Following closely are players like Natalie Sciver-Brunt (83.9%), Marizanne Kapp (80.4%), and Meg Lanning (81.8%), showcasing strong predictions for their significant impact on the league. Notably, the kernel anticipates consistent performances from key players such as Ellyse Perry (78.9%), Deepti Sharma (79.7%), and Smriti Mandhana (74.2%) (Figure 6).

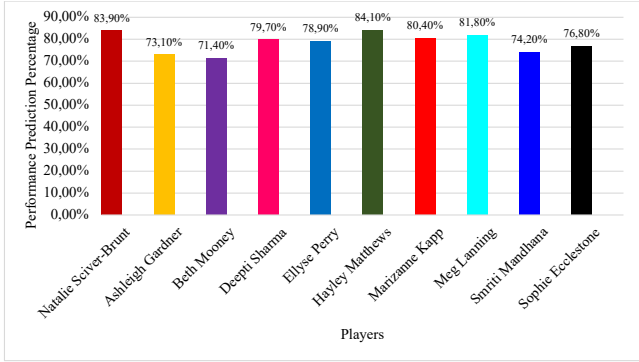

Fig. 6. Prediction of Most Valuable Players for WBL 2024 season based on Inverse MultiQuadratic kernel

Discussion

We looked at how well Support Vector Regression (SVR) kernel models ANOVA, Bessel function, and Inverse MultiQuadratic worked at predicting who would be the most valuable player in the 2024 Women's Premier League (WPL) season. Notably, the kernel exhibits superior predictive accuracy, boasting the lowest mean squared error (MSE), root mean squared error (RMSE), and mean absolute error (MAE), alongside the highest R-squared (R2) (Table 1) (Kaur et al., 2021; Xu et al., 2023).

The implementation of the Inverse MultiQuadratic kernel, which stands out for its radial basis function, displays an impressive predictive accuracy of 86.4% (Figure 4). This outperforms alternatives like ANOVA and the Bessel function, emphasising its proficiency in identifying intricate patterns within the dataset. The visual representation of the performance prediction graph reinforces the reliability of the model, aligning predicted values closely with actual outcomes. Predictions for the most valuable player,

based on this kernel, offer compelling insights. With an 84.1% prediction percentage, Hayley Matthews pulls ahead of Natalie Sciver-Brunt, Marizanne Kapp, and Meg Lanning as the leading contender. Additionally, consistent performances are anticipated from key players such as Ellyse Perry, Deepti Sharma, and Smriti Mandhana, providing valuable information for various stakeholders. The Inverse MultiQuadratic kernel proves to be a standout choice for predicting the most valuable player in the WPL 2024 season. Its efficacy in capturing the dynamics of women's premier league cricket positions it as a valuable tool for stakeholders, aiding in strategic decision-making and enhancing overall understanding of player performances in this evolving sporting landscape (Mandoli et al., 2021; Passi and Pandey, 2018c).

While this research study provides valuable insights, there are opportunities for future exploration and refinement of predictive modeling in women's premier league cricket (Awan et al., 2021). The inclusion of additional features, such as player fitness, team strategies, and external factors like weather conditions, could enhance predictive models. Exploring ensemble methods and hybrid models may further amplify predictive accuracy. Ongoing advancements in data analytics and machine learning techniques call for continuous adaptation and refinement of models. Future research could extend to other cricket leagues or sports, expanding the applicability of predictive analytics in women's sports (Kruglov and Khudolii, 2022: Bullock et al., 2022). In essence, this research lays the groundwork for a dynamic interplay between sports analytics and machine learning in women's premier league cricket. As the sporting landscape evolves, predictive modeling becomes an indispensable tool, offering strategic insights and fostering a deeper understanding of the intricate dynamics influencing player performances (Aburas et al., 2018). Through ongoing research and refinement, the field of sports analytics is poised for continuous growth and contribution to the expanding domain of women's cricket (Simsek et al., 2021).

Conclusions

The Inverse MultiQuadratic kernel emerges as the top performer, displaying superior results across key metrics, including Mean Squared Error (MSE), Root Mean Squared Error (RMSE), Mean Absolute Error (MAE), and R-Squared (R2). Its unique radial basis function and emphasis on proximity contribute to its adeptness in capturing nuanced patterns within the dataset. The predictions based on this kernel for the most valuable player in the upcoming Women's Premier League (WPL) season 2024 reveal intriguing insights into the potential standout performers. Hayley Matthews emerges as a front-runner with a substantial prediction percentage of 84.1%, indicating a high likelihood of her securing the coveted title.

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Conflict of interest

The authors declare that there is no conflict of interest.

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Застосування ядрових моделей опорно-векторної регресії для прогнозування результатів гри в крикет у Жіночій прем'єр-лізі 2024 року

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Історія питання. Інтерес до жіночої прем'єр-ліги з крикету викликав потребу в застосуванні розширеної аналітики для розуміння багатогранної динаміки даного виду спорту.

Мета дослідження. Метою дослідження є внесок у спортивну аналітику шляхом оцінки ефективності застосування ядрових моделей опорно-векторної регресії (ОВР) у прогнозуванні визначення найбільш результативного гравця. Такі

методи дослідження, як дисперсійний аналіз (ANOVA), функція Бесселя та застосування зворотніх мультиквадратичних ядер, були свідомо обрані через їхні різноманітні математичні підходи, що відповідають тонкощам гри в крикет у жіночій прем'єр-лізі.

Матеріали та методи. Результативність гравців було проаналізовано за допомогою наступних методів дослідження: дисперсійний аналіз (ANOVA), функції Бесселя та застосування зворотніх мультиквадратичних ядер. Дані, отримані з сайту espncricinfo.com та Міжнародної ради крикету, включають основні показники для п'яти команд. Ретельні методи попереднього опрацювання, такі як імпутація та виключення відхилень, підвищують достовірність даних, забезпечуючи отримання надійних прогнозних моделей.

Результати. Застосування зворотного мультиквадратичного ядра демонструє виняткову прогностичну ефективність, перевершуючи моделі дисперсійного аналізу (ANOVA) та функції Бесселя. Радіально-базисна функція ядра ефективно відображає складну динаміку жіночої прем'єр-ліги з крикету. Отримані результати підкреслюють доцільність застосування ядрового методу з метою прогнозування найбільш результативних гравців у сезоні Жіночої прем'єр-ліги 2024 року.

Висновки. В результаті дослідження було встановлено динамічну взаємодію між спортивною аналітикою та машинним навчанням у жіночій прем'єр-лізі з крикету. Застосування зворотного мультиквадратичного ядра показало найбільшу ефективність, надаючи ключову інформацію щодо прогнозування результатів гравців. Це підкреслює постійну інтеграцію сучасних аналітичних методів для покращення нашого розуміння динаміки розвитку жіночої прем'єр-ліги з крикету. Оскільки цей вид спорту набуває все більшої популярності на світовій арені, такі аналітичні дослідження стають необхідними для прийняття стратегічних рішень та сталого розвитку.

Ключові слова: жіночий крикет, опорно-векторна регресія, машинне навчання, порівняльний аналіз, прогнозування результатів.

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The Effect of Knee Tuck Jump and Jump-To-Box Plyometric Training on Female Students' Leg Muscle Strength and Flexibility in Volleyball Extracurricular Activity

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Abstract

Study purpose. This study aimed to investigate the effects of Knee Tuck Jump or Jump to Box plyometric training and to determine their effectiveness in increasing leg muscle strength and flexibility in female students participating in volleyball extracurriculars.

Materials and methods. This study used a quasi-experimental design. Twenty-four female students were randomly selected as samples and then divided into two categories: 12 students receiving Knee Tuck Jump training (age: 17.08±0.51) and 12 students receiving Jump to Box training (age: 17.00±0.60). All participants performed the initial and final tests using the Vertical Jump and sit-and-reach tests. To analyze the data, the t-test was used to determine the differences in variables between the pretest and posttest in the experimental group.

Results. In the Knee Tuck Jump group, a significant improvement in VJ ($p = 0.000$) and sit-&-reach tests ($p = 0.000$) was observed. In addition, Knee Tuck Jump was considered to be more effective in increasing the students' flexibility, because the t value of sit-&-reach test (14.075) was higher than that of VJ (13.811).

Similarly, the Jump to Box group also showed a significant improvement in VJ ($p = 0.000$) and sit-&-reach ($p = 0.000$) tests. However, Jump to Box was deemed to be more effective in increasing the students' leg muscle strength, as the t value of VJ (26.086) was higher than that of sit-&-reach test (9.594).

Conclusions. Based on the research findings, it can be concluded that plyometric exercises, specifically KTJ and JB, have a significant and positive impact on the lower limb muscle strength and flexibility in female students participating in volleyball extracurricular activities. Despite both demonstrating significant positive effects, KTJ training is more effective in improving flexibility compared to JB, while JB is more effective in enhancing lower limb muscle strength compared to KTJ.

Keywords: plyometric training, flexibility, volleyball, female student.

Introduction

Volleyball demands a unique skill to land the ball in the opponent's area, and to achieve maximum performance, the players must be in top physical condition (Bompa & Carrera, 2015; M. Silva et al., 2014). Athlete performance, particularly in sporting events, is greatly improved by physical condition. Athletes will benefit from being in good physical shape as they learn sports techniques. The primary objective of enhancing sports performance is the capacity of personally trained athletes (Gozzoli et al., 2023). Forearm pass, overhand pass, serve, smash and block are some examples of basic individual skills in the game of volleyball (Zahálka et al., 2017). These individual basic skills all utilize various motor skills and abilities such as jumping, swinging or various ways of movement as well as strength, agility, flexibility and reaction speed (Lehnert et al., 2017).

According to the components of physical condition, volleyball players need endurance, speed, strength, power, flexibility, and agility (Charitonidis et al., 2019). Each player in an international men's volleyball match makes more than 250 jumps during the course of the five sets, according to

match analysis (Martinez, 2017). According to Vlantes & Readdy (2017), the team and the volleyball players themselves will benefit from having a good jump, making it advantageous to have a strong physical power component in volleyball games.

Furthermore, power training is frequently used in volleyball, which is regarded as a very explosive and fast-paced activity (A. F. Silva et al., 2019). One of the most crucial skills to master to become a competent or experienced player in volleyball is jumping. The ability to jump high is necessary for success when performing a smash. Physical components like leg muscle power and flexibility are required to increase smashing skills. Leg muscle power affects jumps during smashing and blocking (Hammami et al., 2022). At the same time, flexibility is also needed to support athletes in performing smashes. According to Hu et al. (2022), the degree of a joint's flexibility determines how well it can carry out specific movements. Additionally, Zhao & Liu (2022) stated an athlete's speed, strength, and explosive power can all be improved to various degrees by training flexibility. Flexibility is therefore required when blocking and striking the ball. In a volleyball match, a good smash will result in points by dropping the ball in the opponent's area. The players must also be in decent physical shape to achieve strong smash results. According to A. F. Silva et al. (2019), it is necessary to make efforts to increase physical quality through various training methods in order to obtain maximum processing in volleyball games, particularly boosting leg muscle power and flexibility in every volleyball game.

The plyometric approach is one exercise strategy for boosting power (Slimani et al., 2016). Plyometrics is one of the training techniques that trainers are frequently requesting to increase the physical component of power, especially in sports that require the use of the legs or arms. However, its effect on flexibility has not been investigated. Additionally, plyometric exercise involves training by umping or bouncing using the limbs (Davies et al., 2015). The knee tuck jump exercise, which is performed in a sequence of quick, explosive jumps, is one example. The gastrocnemius, gluteals, quadriceps, hamstrings, and hip and thigh flexors are among the muscles that develop in this exercise (Clark et al., 2018). Another example is the jump-to-box exercise, which is the exercise of jumping onto a block box and then jumping back down to the back using the starting position and both legs together (Saparia et al., 2020).

Based on the explanation above, this research aimed to reveal the effect of plyometric training on strength and flexibility. Specifically, it compared the effect of plyometric knee tuck jump and jump to box exercises on increasing the students' strength and flexibility. Because the students participated in extracurricular volleyball activities, they could be categorized as unprofessional volleyball players (beginners).

Materials and methods

Participants

Twenty-four students from one senior high school who joined volleyball extracurriculars agreed to participate in this research. After a preliminary assessment using the vertical jump and sit-and-reach, the participants were then randomly split into two groups, one received plyometric training in the knee tuck jump (KTJ) and one received jump to box (JB). Table 1 displays the characteristics of the students. All students had no experience in weight training. They were initially given an explanation of the benefits and risks that could occur if they took part in the training in this research. Then, they provided written consent to the experimental procedures.

Table 1. Participant's physical characteristics

Variables	Knee Tuck Jump (n = 12)	Jump To Box (n = 12)
	Mean ± SD	Mean ± SD
Age	17.08±0.51	17.00±0.60
Height (m)	1.56±0.01	1.57±0.02
Weight (kg)	44.25±6.20	48.33±6.12
BMI	18.11±2.43	19.71±2.45

Experimental design

This study was designed to answer two questions: (1) Is there an effect of plyometric knee tuck jump and jump-to-box exercises on strength and flexibility? (2) Is plyometric knee tuck jump training more effective for increasing strength and flexibility? To investigate these questions, twenty-four students were randomly assigned to one of the two training groups: KTJ (n = 12) and JB (n = 12). This research used a quasi-experimental design. The two experimental groups trained twice a week for 6 weeks using only plyometric knee tuck jump (KTJ) and jump to box (JB) exercises with their own body weight and using equipment in the form of a 40cm high box. The following are the characteristics of the training program in this research

Table 2. Characteristics of the training program*

Indexes		KTJ (S × R × I)	JB (S × R × I) (cm)
Week 1	TS1	2 × 6 × 30"	2 × 6 × 30" × 40cm
	TS2	3 × 6 × 30"	3× 6 × 30" × 40cm
Week 2	TS3	2 × 8 × 30"	2 × 8 × 30" × 40 cm
	TS4	3 × 8 × 30"	3 × 8 × 30" × 40cm
Week 3	TS5	2 × 10 × 1'	2 × 10 × 1' × 40cm
	TS6	3 × 10 × 1'	3 × 10 × 1' × 40cm
Week 4	TS7	4 × 8 × 2'	4 × 8 × 2' × 40cm
	TS8	4 × 10 × 2'	4 × 10 × 2' × 40cm
Week 5	TS9	4 × 12 × 2'	4 × 12 × 2' × 40cm
	TS10	4 × 15 × 3'	4 × 15 × 3' × 40cm
Week 6	TS11	5 × 15 × 4'	5 × 15 × 4' × 40cm
	TS12	5 × 15 × 3'	5 × 15 × 3' × 40cm

*note: TS: Training session; KTJ: Knee tuck jump; JB: Jump to Box (cm); S × R × I: Set × Repetitions × Interval (minute)

Testing procedure

The testing session was conducted for each participant in the same condition, without injury, and not following

a match or a period of intense training at the same location and time (about an hour). During testing, body composition was also assessed. The participants were verbally strongly encouraged to exert their maximum effort. They were also recommended to stretch for roughly 10 minutes prior to the test.

Vertical Jump (VJ)

VJ is used to evaluate lower body strength in the vertical plane in an indirect manner (Banda et al., 2019). The tools used were a board attached to the wall at a height of 150 to 350 cm, powdered chalk (talcum powder or flour), and a blackboard eraser. To carry it out, first the fingertips were smeared with lime powder or magnesium carbonate, then the participant stood upright near the wall, feet together, scale board to the left or right. Next, the hand near the wall was lifted straight up, the palm of the hand was placed on a scaled board, thereby leaving a reach mark. Participants started with a bent knee posture and the dominant hand or arm was raised in a vertical position and the other arm was hanging at the side of the body and was not permitted to swing the arm to help with jumping momentum. Then the participants jumped as high as possible while tapping the board with their fingertips to leave a mark. The assessment is the difference in jumping achievement minus standing achievement. The participants got two opportunities to do this test. The best results were recorded.

Sit and Reach

Flexibility was assessed using sit and reach test. The subjects sat with their feet approximately hip-wide against the testing box. They kept their knees extended and placed the right hand over the left, and slowly reached forward as far as they could by sliding their hands along the measuring board. The participants got two chances to do the test and the best results were recorded.

Statistical analysis

In analyzing the data, the following tests were used:

(1) Normality test to find out whether the data were normally distributed. The test used was the Shapiro-Wilk test;

(2) Homogeneity test to find out whether the variations in the population were the same or not. The homogeneity of variance test was carried out to test the similarity of the variances of the pretest and posttest experimental group data. To test the homogeneity, the Levene's Test with the F test was used. The homogeneity test was carried out to determine whether the data distribution (variance) of the two experimental groups was not heterogeneous, in the sense that they had balanced traits or characteristics so that they were suitable for comparison (van Breukelen & Candel, 2021). The data distribution (variance) of the two experimental groups was declared homogeneous if the Levene test results showed a significance value of $p>0.05$;

(3) The t-test was carried out to determine whether there were differences in variables between the pretest and posttest in the experimental group. A difference could be stated if the significance value was less than 0.05 ($p < 0.05$). The data obtained from the initial test (pretest) and final test (posttest) were analyzed descriptively statistically using the t-test using the SPSS version 27 with a significance level of 5% or 0.05.

Results

Pre-Test Results

A statistical picture is shown in Table 3 based on assessments of students' strength and flexibility before knee tuck jump or jump to box training. Based on the table, it can be seen that in the knee tuck jump group the students had an average strength value of 27,916 and flexibility with an average value of 23,495. Meanwhile, in jump to box group, the average strength value was 26.9167 and the average flexibility value was 19.050.

Table 3. Statistical Description of Pre-Test Score

Indexes	Knee Tuck Jump group pre-test score (n = 12)		Jump to Box group pre-test score (n = 12)	
	Strength	Flexibility	Strength	Flexibility
Mean	27.9167	23.4950	26.9167	19.0500
Median	28.0000	22.8600	27.0000	19.0500
Std. Deviation	1.88092	3.77132	2.23437	2.54000
Variance	3.538	14.223	4.992	6.452
Range	6.00	12.70	7.00	7.62
Minimum	25.00	17.78	23.00	15.24
Maximum	31.00	30.48	30.00	22.86

Post-Test Results

Table 4 shows descriptive data from the results of measuring strength and flexibility after treatment was given, namely knee tuck jump and jump to box exercises.

Table 4. Statistical Description of Post-Test Score

Indexes	Knee Tuck Jump group post-test score (n = 12)		Jump to Box group post-test score (n = 12)	
	Strength	Flexibility	Strength	Flexibility
Mean	37.5833	32.1792	40.3333	26.2083
Median	38.0000	32.9000	40.5000	25.2500
Std. Deviation	1.44338	2.83929	1.82574	3.79867
Variance	2.083	8.062	3.333	14.430
Range	5.00	11.00	6.00	12.00
Minimum	35.00	26.00	37.00	22.00
Maximum	40.00	37.00	43.00	34.00

After the treatment it can be seen that in knee tuck jump group the students had an average strength value of 37.5833 and average flexibility value of 32.1792. Meanwhile, in jump to box group, the students' average strength value was 40.3333 and their average flexibility value was 26.2083. Therefore, it may be considered that the jump to box exercise is more helpful for increasing strength, while the knee tuck jump exercise is more effective for increasing flexibility. However, these descriptive data need to be strengthened in order for them to provide a substantial and meaningful answer to the hypothesis.

Normality Test Results

The Shapiro-Wilk test was used to test the normality. Table 5 explains that all data were normally distributed because all results got significant values below 0.05.

Table 5. Normality Test Results

Group	Variables	Pre-test		Post-test	
		s-w	P	s-w	p
KTJ	V-Jump	0.944	0.552	0.960	0.780
	Sit & Reach	0.933	0.411	0.936	0.453
JB	V-Jump	0.962	0.811	0.955	0.713
	Sit & Reach	0.906	0.187	0.866	0.058

Homogeneity Test Results

The Levene Statistic test was performed to test the homogeneity. Tabel 6 shows that all data were homogeneously distributed because all results obtained significant values below 0.05

Table 6. Homogeneity Test Results

Groups	Variables	Levene Statistic	p
KTJ	V-Jump	.478	.497
	Sit & Reach	1.128	.300
JB	V-Jump	.337	.567
	Sit & Reach	1.064	.313

Hypothesis Testing

Hypothesis testing was then conducted after the data passed the prerequisite test, indicating that the data were homogeneous and normally distributed. The purpose of this study was to determine whether plyometric knee tuck jump and jump to box exercises had an impact on strength and flexibility and to determine which activity was more successful at doing so. The following are the results of the Paired Sample T-test to answer the hypothesis in this research.

According to Table 7, knee tuck jump group had a significant improvement in vertical jump because the p-value was less than 0.05 and the t statistic was positive. Additionally, there was a significant improvement in sit and reach because the p-value was below 0.05 and t statistic was positive. Therefore, it can be concluded that Knee tuck jump is more effective to increase the students' flexibility because the t statistic of Sit and reach (14.075) was higher than that of Vertical jump (13.811).

Similarly, in jump to box group, a significant improvement was observed in vertical jump as the p-value was less than 0.05 and t statistic was positive. Similar improvement was also seen in sit and reach because, once again, the p-value was below 0.05 and t statistic was positive. However, jump to box exercise is considered more effective to improve the students' leg muscle strength because the t statistic of Vertical jump (26.086) was higher than that of sit and reach (9.594).

Discussion

The effects of Jump to Box plyometric training on leg muscle strength and flexibility

Plyometric exercises are designed to enhance neuromuscular coordination by conditioning the neural system and increasing movement automaticity when engaged in activity. As a result, activity automation is known to be created, strengthening motor patterns, which boosts neural efficiency and enhances neuromuscular performance (Davies et al., 2015). Plyometrics is known as a stretch-shortening cycle, or mitotic stretch reflex, where a muscle is loaded into an eccentric contraction (lengthening), followed immediately by a concentric contraction (shortening) with the result that the muscle that was stretched before the contraction will contract more forcefully. Plyometrics also include vigorous and explosive training exercises to activate the fast response and elastic properties of the major muscles in the body. Thus, implementing a specific strength and conditioning program in volleyball can significantly help prevent injuries and improve performance.

Since volleyball players place a high value on being able to jump vertically, it is thought that using plyometric training techniques to increase this capacity may enhance volleyball player performance (Çankaya et al., 2018). A study by Mroczek et al. (2018) has found that plyometric training contributes to optimizing landing mechanisms, improving extrinsic muscle control and increasing knee flexion and hamstring activity.

The variety of exercises is another crucial element that might impact the efficacy or scope of the advantages of plyometric intervention. In this research, the jump to box exercise was utilized to train the students' strength and flexibility. According to the findings of this study, using such exercise significantly influences the students' leg muscle strength and flexibility. This finding is strengthened by the

Table 7. Results of Hypothesis Testing

Variables		Test	KTJ Group			JB Groups		
			Average	t count	p value	Average	t count	p value
Strength	V-Jump	Pretest	37.58	13.811	0.000	40.33	26.086	0.000
		Posttest	27.91			26.91		
Flexibility	Sit & Reach	Pretest	32.17	14.075	0.000	26.20	9.594	0.000
		Posttest	23.49			19.05		

study by Gjinovci et al. (2017) which found plyometric training (which included jump to box exercise) more effective than skill-based conditioning in increasing the conditioning capacity of female senior volleyball players with the results of the plyometric group significantly reducing body mass (Effect Size [ES] difference; average 1% change before and after measurement), and improved their performance in S20M (moderate ES; 8%), MBT (very large ES; 25%), CMJ (large ES; 27%), and SBJ (moderate ES; 8%).

In addition, a significant effect of jump to box training was observed on the students' flexibility with a significant value of 0.000. This is in line with the study by Ramírez-delaCruz et al. (2022) which found that plyometric training increased the thickness, pennation angle and length of the muscle fascicles evaluated. Additionally, plyometrics is an effective tool for increasing tendon stiffness and improving jumping performance and lower body strength. According to Arntz et al. (2022), plyometric jump training can cause skeletal muscle hypertrophy, regardless of age and gender. There is evidence of a relatively greater effect in non-athletes compared to athletes.

Although jump to box exercise was observed to significantly impact the students' vertical jump and flexibility, this exercise is deemed to be more effective to increase the students' leg muscle strength because the t statistic of Vertical jump (26.086) is higher than that of Sit and reach (9.594). Since vertical jumps are not the only thing that volleyball players do, future research on volleyball players must include a variety of vertical jump tests to compare the various effects of plyometric training on player performance, particularly in volleyball players. Additionally, it is necessary to assess how various programs affect players who are more experienced and skilled.

The effects of plyometric Knee Tuck Jump training on leg muscle strength and flexibility

The range of motion that may be performed without injuring a joint or group of joints is determined by flexibility, which is a feature fundamental to bodily tissue (Pate et al., 2012). The sit and reach test is used to measure spinal flexibility and hamstring muscle length (Cornbleet & Woolsey, 1996). According to studies by Idrizovic et al. (2018) and Turgut et al. (2016), plyometric training improves flexibility in women under 16. However, on the other hand, flexibility ability as measured by sit and reach in middle school students is considered to reduce vertical jump ability. Refuting previous research findings, Ozgul (2018) revealed that static, dynamic and PNF flexibility training improved the vertical jump performance of basketball and volleyball players. Research by Yildiz et al. (2020) revealed that, static stretching increased flexibility but decreased the athletes' jumping performance.

A study by Skaggs et al. (2015) which compared the individual and combined effects of plyometric training programs and dynamic stretching on muscle strength, endurance, and flexibility in female collegiate volleyball players, showed that plyometric training improved some of these neural functions and dynamics, so it could be concluded that stretching increased muscle temperature, stimulated nervous system and increases muscle elasticity, thereby increasing flexibility by 10.29%.

This research has found that plyometric training using the Knee Tuck Jump method which is carried out systematically with the correct frequency and intensity can increase the students' leg muscle strength. A significant improvement was seen in the students' vertical jump as the p-value was below 0.05 and the t statistic was positive. Furthermore, similar improvement was observed in the students' sit and reach test because the p-value was below 0.05 and the t statistic was positive. Therefore, it can be concluded that Knee tuck jump exercise is considered more effective to improve the students' flexibility since the t statistic of Sit and reach (14.075) is higher than that of Vertical jump (13.811). This can happen because the knee tuck jump training mechanism emphasizes the maximum height achieved by pushing the leg up and forward quickly, especially by training the flexors and extensors of the thigh and hip in relation to muscles such as the iliacus, sartorius, gracilis, biceps, femur, semitendon, gluteus muscle, semi-membrane, gluteus major and minor. This repetitive jumping movement will contract the leg muscles and increase the size and number of muscle cells and leg muscle fibers which will indirectly have an effect on increasing flexibility. Flexibility depends on several factors such as joint structure, body muscles, flexibility of capsule and collagen tissue, strength and evenness of joints of bony structures, intramuscular and intermuscular coordination, age, psychology, environmental conditions, level of training, fatigue and warming up. Furthermore, to support this study's findings, a study by Tsolakis & Bogdanis, (2012) found that there was an increase in hip flexion ROM (~12.6%), but there was a significant decrease in CMJ performance of 5.5% due to long duration static stretching treatment. This static stretching or lowering effect still occurs for a moment when doing a tuck jump. Furthermore, CMJ's performance returned to its initial performance (initial measurement) only after performing tuck jumps for 8 minutes.

Future studies should look at the range of motion during plyometric training in order to identify the factors most likely to increase participants' flexibility. Additionally, it is necessary to assess how various programs affect professional and skilled players.

Conclusions

Based on the study' findings, it can be concluded that Knee Tuck Jump and Jump to Box plyometric exercises have a positive and significant influence on the beginner female volleyball players' leg muscle strength and flexibility. Although both have a significant positive effect, Knee Tuck Jump training is more effective at increasing flexibility, while Jump to Box is more effective at increasing leg muscle strength. Further research needs to be carried out to further strengthen this research's findings by investigating the effects of both exercises on experienced and more professional players.

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Conflict of interest

The authors guarantee that no conflicts of interest exist.

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Вплив пліометричного тренування стрибків із підтягуванням колін до грудей та стрибків на коробку (пліобокс) на показники сили м'язів ніг та гнучкості у студенток в процесі позааудиторних занять з волейболу

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 8 с., 7 табл., 33 джерела.

Мета дослідження. Метою цього дослідження було вивчити вплив пліометричного тренування стрибків із підтягуванням колін до грудей або стрибків на коробку (пліобокс) та визначити їх ефективність у зростанні показників сили м'язів ніг та гнучкості у студенток, які беруть участь у позааудиторних заняттях з волейболу.

Матеріали та методи. У цьому дослідженні використано квазіекспериментальний метод. Двадцять чотири студентки були відібрані методом рандомізації, а потім розподілені на дві категорії: 12 студенток, які виконували тренування зі стрибків із підтягуванням колін до грудей (вік: 17,08±0,51) та 12 студенток, які виконували тренування зі стрибків на коробку (вік: 17,00±0,60). Всі учасниці виконували початкові та підсумкові випробування, виконуючи вертикальний стрибок та тест на гнучкість sit-and-reach (спосіб вимірювання загальної гнучкості тіла при згинанні тулуба вперед, сидячи на підлозі з витягнутими вперед руками). Для аналізу даних було застосовано t-критерій для визначення відмінностей у показниках варіації змінних між претестом і посттестом в експериментальній групі.

Результати. У групі, що виконувала вправи зі стрибків із підтягуванням колін до грудей, спостерігалося значне покращення показників результативності у тесті з виконання вертикального стрибка (p=0,000) та тесті на гнучкість sit-and-reach (p=0,000). Крім того, стрибок із підтягуванням колін до грудей виявився більш ефективним в рамках зростання показників гнучкості студенток, оскільки t-статистика (значення) тесту на гнучкість sit-and-reach (14,075) була вищою, ніж при виконанні вертикального стрибка (13,811).

Аналогічним чином, група, яка виконувала вправи зі стрибків на коробку (пліобокс) також показала значне поліпшення результативності у тесті з вертикального стрибка (p=0,000) та тесті на гнучкість sit-and-reach (p=0,000). Однак, стрибок на коробку виявився більш ефективним у зростанні показників сили м'язів ніг студенток, оскільки t-значення вертикального стрибка (26,086) було вищим, ніж при виконанні тесту на гнучкість sit-and-reach (9,594).

Висновки. На основі результатів дослідження можна зробити висновок, що пліометричні вправи, зокрема стрибки із підтягуванням колін до грудей та стрибки на коробку, мають значний позитивний вплив на показники сили м'язів нижніх кінцівок та гнучкості у студенток, які беруть участь у позааудиторних заняттях з волейболу. Незважаючи на те,

що обидві вправи демонструють значні позитивні результати, тренування зі стрибків із підтягуванням колін до грудей є більш ефективним для поліпшення показників гнучкості порівняно з виконанням стрибків на коробку, тоді як стрибок на коробку є більш ефективним для підвищення показників сили м'язів нижніх кінцівок порівняно з виконанням стрибків із підтягуванням колін до грудей.

Ключові слова: пліометричне тренування, гнучкість, волейбол, студентка.

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The Influence of Physical Education Over A Semester on the Psycho-Physical Development in Elementary School Students

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Abstract

Study purpose. The aim of this study was to determine the impact of the physical education program over a semester on physical fitness, sport-specific skills (football and basketball) and the quality of life in elementary school students (7th and 8th grade).

Materials and methods. 128 students (64 boys and 64 girls) from three elementary schools, aged 13–14, participated in the study. A battery of five diagnostic tests was used to assess physical fitness: Modified Agility "T" test, Illinois Agility Run Test, 10x5 Shuttle Run Test, Standing Balance Test and 2-Minute Step in Place Test. Training polygons with elements of sports were used to assess football and basketball skills. Determining the level of quality of life was carried out with a pediatric quality of life questionnaire (Pediatric Quality of Life Inventory TM – PedsQL).

Results. The study found statistically significant improvements in the results of most physical fitness tests in all team sports on training polygons, as well as in the level of quality of life for both boys and girls in both grades.

Conclusion. It can be concluded that the physical education program was well organized and implemented and thus had a positive effect on improving the psycho-physical status of students.

Keywords: physical fitness, quality of life, children, football, basketball.

Introduction

The physical education program is characterized by the use of a large number of aerobic and anaerobic physical activities (Deng, Zhang & Chen, 2021), which influence the improvement of children's physical status, their training and practicing various motor skills (basic and sports-specific) and contribute to the development of psycho-social characteristics of children (Milenković, 2021). Attending a physical education program contributes to the development of physical fitness, acquiring knowledge and motor skills (Faigenbaum et al., 2015). Simultaneously, the frequent negative phenomenon in the form of physical inactivity among children can be suppressed with an effective physical education program (Habyarimana, Tugirumukiza & Zhou, 2022; Wintle, 2022). In this way, potential health problems such as obesity and hypertension can be prevented (Hills, Andersen & Byrne, 2011; Aguilar-Cordero et al., 2020). All this further affects the overall level of quality of life in children (Bermejo-Cantarero et al., 2021).

The development of physical fitness has been done through organized and systematic physical exercise. In physical education classes, the improvement of physical fitness is not too great because of the small scope and intensity of work, however, with proper and optimal work, it is possible to influence adaptive changes in the level of physical fitness of students (Milenković, Karalejić, Savić & Milenković, 2013). In addition to the development of physical fitness, the physical education program also contributes to the training and practice of sport-specific skills which physical fitness is significantly related to (Milenković, Branković, Petković, Kostić & Stanković, 2008; Kokstejn, Musalek, Wolanski, Murawska-Cialowicz & Stastny, 2019; Milenković, 2022). As part of the work on the development of sport-specific skills in the physical education program, technical elements from

team sports, soccer and basketball are also used, which are related to manipulating the ball and accuracy of hitting the target.

Soccer practice, in addition to learning and practicing simple technical elements, also stimulates the motor and cognitive development of children, especially the ability to sustain attention. During the soccer game, the participant analyzes the changing situations through perception and realizes them using his cognitive abilities, thereby executing his decision using his technical and kinetic abilities (Alesi et al., 2015). The specificity of soccer is reflected in polystructural complex acyclic and cyclic movements with or without the ball, which are manifested through one or more motor dimensions. The efficiency of movement is based on a rational technique that enables the full motoric potential of the player/student (Milenković, Pelemiš & Branković, 2011). Basketball consists of complexes of simple and complex movements with a combination of cyclic and acyclic movements with frequent periods of high-intensity play and frequent changes in the direction of movement (Stanković, Lazić, Milenković, Nurkić & Kocić, 2022). Playing basketball successfully, which is classified as a complex anaerobic sport, requires endurance, precision, speed, agility, explosive strength, as well as cognitive abilities (Kocić, 2008; Ademović, 2015; Cao et al., 2022). These team sports have a very significant place in the physical education program, both in compulsory and optional activities due to their popularity among students (Kim et al., 2022).

The connection between the level of physical activity and quality of life in children and adolescents is the subject of many studies (Janssen & LeBlanc, 2010; Tremblay et al., 2011; Wu et al., 2017; Wunsch et al., 2021). A higher level of physical activity improves quality of life both physically and mentally (Marker, Steele & Noser, 2018). Success in completing the tasks provided by the physical education program and optimal physical development contributes to students' self-confidence in other areas of learning and work (Bailey, 2018).

Based on theoretical assumptions, the aim of this research was to determine the impact of the physical education program over a semester on physical fitness, sports-specific skills and the quality of life of elementary school students. It is assumed that there is a positive influence of the physical education program on the mentioned elements of psychophysical development of children. When talking about the importance of this research, it should be noted that it is important to identify the level of impact of the physical education program on students, that is, how effective it is in improving physical fitness, motor skills and knowledge and preserving health in modern living and working conditions.

Materials and methods

Participants

A sample of 128 children, aged 13–14, was drawn from three elementary schools. They participated in two testings that were conducted at the beginning and at the end of the first semester of the school year 2022–23. Regular attendance of physical education classes was a criterion for inclusion in the research. The sample was further divided into students of the seventh (32 male and 32 female) and of the eighth grade (32 male and 32 female).

The school authorities, the children's parents, as well as the children themselves gave the consent for testing the students. The research was approved by the Ethics Committee of the Faculty of Sports, Union University – Nikola Tesla in Belgrade (code: 172/22).

Measuring instruments

Physical Fitness

A battery of five diagnostic tests (Wood, 2008) was used to test physical fitness. The previous research has established that these tests are reliable and valid for assessing physical fitness: Modified agility "T" test – MAT (Sassi, et al., 2009); Illinois agility run test (Hachana et al., 2014); 10×5 shuttle test (Boddington, Lambert, St Clair Gibson & Noakes, 2001); Standing balance test (Geldhof et al., 2006); 2-minute step in place test (Haas, Sweeney, Pierre, Plusch & Whiteson, 2017).

Sport Polygons

To assess the sport-specific skills, polygons which contain the basic technical elements of soccer and basketball were used, those ones which have already been studied in the older grades of elementary school (grades 7th and 8th).

Description of the soccer polygon (Fig. 1). From the starting position (point A), the student starts a curvilinear movement between the cones (slalom) during which he dribbles the soccer ball in a length of 10 meters (slalom starts from the left side of the first cone). After exiting the slalom, the student passes the ball towards the wall, which is 5 meters away. After the ball bounces off the wall, the student receives the ball and returns the same way by curvilinear movement between the cones by entering the slalom from the left side of the first cone. After exiting the slalom from point B, he shoots the ball towards a small soccer goal measuring 1×0.5 meters, located at a distance of 5 meters. A shot on goal marks the end of the polygon and measuring the time. For missing a goal, two seconds are added to the total time. For a task done incorrectly (wrong movement, knocking down a cone, going around the cone from the wrong side, etc.) one second is added to the total time.

Description of the basketball polygon (Fig. 2). From the starting position (point A), the student takes the first ball from the hoop and uses both hands to shoot at a horizontal target (basket for balls) 5 meters away using the technique of passing from the chest. Afterwards, he takes the next ball from the hoop with which he performs a curvilinear movement (driving the ball – dribble) between the cones over a length of 10 meters by entering the slalom from the right side of the first cone. The ball is guided alternately with both hands in all phases of the polygon. After exiting the slalom, the student passes the ball towards the wall 3 meters away. The ball is passed with both hands from the chest and on the floor. After the ball bounces off the wall, the student catches the ball and returns the same way by curvilinear movement between the cones by entering the slalom from the left side of the first cone. After exiting the slalom, the student guides the ball in a straight line in a length of 5 meters to point B, from which a jump shot is made at the basket. After the shot, the student takes the ball and takes it back to the hoop where he drops it, which marks the end of the polygon and measuring the time. Two seconds are added

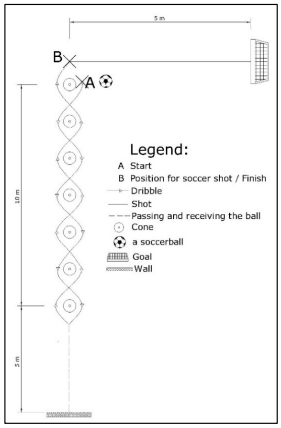

Fig. 1. Soccer Polygon

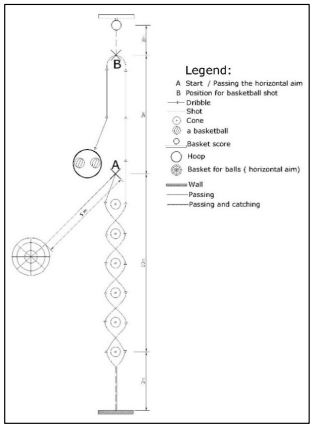

Fig. 2. Basketball Polygon

to the total time for each missed goal (basket, hoop). For a task done incorrectly (wrong movement, knocking down a cone, going around the cone from the wrong side, etc.) one second is added to the total time.

Quality of life questionnaire

Determining the level of health-related quality of life was carried out with a pediatric quality of life questionnaire (Pediatric Quality of Life InventoryTM – PedsQL) (Varni, Seid, Rode, 1999). The questionnaire is intended to assess the health-related quality of life of children and adolescents aged 5-18. This questionnaire is composed of 23 statements with a five-point Likert-type scale offered for giving the degree of agreement for a given statement. The offered degrees of agreement range from: 1 – I do not agree at all, to 5 – I completely agree. Conceptually, the PedsQL measures general well-being and functioning in daily life independent of the child's health status. It has been culturally adapted and validated for the Serbian language (Stevanović, Lakić, Damnjanović, 2011). The questionnaire consists of four subscales: Physical functioning (5 items), Emotional functioning (8 items), Social functioning (5 items), School functioning (5 items). The sum of the scores of all scales represents the overall quality of life. The reliabilities (Krombach's alpha coefficient) of the scales of this instrument are high (physical functioning α=0.64, emotional functioning α=0.68, social functioning α=0.75, school functioning α=0.57, psycho-social functioning α=0.73).

Physical education program

Physical education programs for the seventh and eighth grade of elementary school according to the Rulebook of the Ministry of Education, Science and Technological Development of the Republic of Serbia (Službeni glasnik Republike Srbije – Prosvetni glasnik (Official Gazette of the Republic of Serbia – Educational Gazzette), 2019a, 2019b) foresee the same teaching contents that are planned based on the assessment of their complexity for students, as well as facilities for the implementation of the program. So, first for all, there is a possibility of replacing certain teaching contents with some other teaching topics (e.g. sports or activities previously not included) depending on the existence of appropriate facilities. Secondly, their number of classes can be distributed to other teaching contents already existed in the program. Individual teaching contents within the program, in the form of basic and extended parts, are realized three times a week for 45 minutes.

Table 1. Course contents that were performed in the first semester

Content name	no. of classes
Athletics	7
Artistic gymnastics	7
Soccer	10
Basketball	10
Rhythmics and dance	4
Optional activities – the program offers a number of different activities from which students can choose the ones the school has the facilities for (e.g. fitness training, badminton, table tennis, orienteering, martial arts, self-defense, sports that have already been involved in the compulsory program, training, practicing and improving the elements provided by the expanded parts of the teaching contents, etc.).	5
Polygons	3
Swimming and water polo (in the schools where there are not the facilities for performing these activities, that number of classes is distributed to other contents)	5
Testing and Measuring	3

Testing Procedure

The testings was done outdoors, on the open school grounds and in the gymnasium during physical education classes. Regardless of the experience with the testing procedure that the students had acquired during physical education classes in previous grades, in order to ensure the accuracy of the implementation, the students tried out all the tests two days earlier in trial testing to be prepared for the complete procedure during the main testing. Before each testing procedure (initial and final) a 15-minute warm-up was performed. In order to avoid negative effects on testing caused by fatigue there was a 1–2 minute rest period after completing each individual test and before moving on to the next one. At the beginning of the class before testing physical fitness and sport-specific skills, the pediatric questionnaire on quality of life was filled out.

Statistical analysis

Apart from the descriptive parameters (Mean±St.Dev), the T test for dependent samples was used to determine the difference between the initial and final testing. The statistical package SPSS v.20.0 (IBM SPSS Statistics) was used for data processing. Statistical significance was established at the $p \leq 0.050$ level.

Results

This chapter presents the research results and their interpretation. Tables 1 and 2 show the basic statistical data (Mean±SD) as well as the differences between the two tests,

Table 2. Pre- and post-test results in Mean±SD for 7th grade students

	Boys (32)			Girls (32)		
	Pre-test	**Post-test**	**p**	**Pre-test**	**Post-test**	**p**
MAT	8.29±1.25	7.93±1.16	<0.001*	9.32±0.96	8.85±0.92	<0.001*
ILL	20.55±2.34	19.38±1.83	<0.001*	23.13±2.29	21.93±1.92	<0.001*
10×5	14.93±1.26	14.39±1.04	<0.001*	16.46±1.5	15.84±1.23	<0.001*
SBT	20.11±10.19	20.98±8.44	0.113	18.16±7.44	20.22±5.25	0.002*
2-min	129.69±8.14	131.16±6.30	0.001*	121.41±4.88	122.75±3.84	<0.001*
Soccer	24.99±4.92	24.23±4.72	<0.001*	29.41±2.6	27.90±1.92	<0.001*
Basketball	23.81±3.33	22.93±3.13	<0.001*	26.22±1.97	24.51±1.78	<0.001*
PQL	78.19±11.32	84.01±8.08	<0.001*	77.85±6.20	85.39±4.73	<0.001*

* Significance level – $p \leq 0.050$; MAT – modified agility T test; ILL – illinois agility run test; 10x5 – 10x5 shuttle test; SBT – standing balance test; 2-min – 2-minute step in place test; PQL – pediatric quality of life.

Table 3. Pre- and post-test results in Mean±SD for 8th grade students

	Boys (32)			Girls (32)		
	Pre-test	**Post-test**	**p**	**Pre-test**	**Post-test**	**p**
MAT	7.7±0.98	7.24±0.81	<0.001*	7.81±0.99	7.35±0.92	<0.001*
ILL	19.46±2.46	18.38±1.84	<0.001*	22.41±2.23	21.07±1.96	<0.001*
10×5	15.56±2.74	14.61±1.66	<0.001*	15.58±1.32	14.93±1.11	<0.001*
SBT	17.16±7.9	19.00±4.97	0.017*	18.59±6.67	19.92±5.51	0.075
2-min	126.84±7.23	128.62±5.58	<0.001*	124.06±4.58	125.09±3.7	<0.001*
Soccer	21.25±4.4	20.18±3.25	<0.001*	23.86±3.07	22.77±2.94	<0.001*
Basketball	24.85±2.9	22.88±2.04	<0.001*	23.28±2.16	22.28±2.19	<0.001*
PQL	76.8±6.71	85.29±4.64	<0.001*	81.92±9.66	86.31±6.65	<0.001*

before the beginning and after the end of physical education classes in the first semester. All results are shown separately for boys and for girls.

The results of two tests of male and female students of the seventh grade presented in Table 2, point out that there are statistically significant differences in all three areas examined in this research. In boys, only one test of physical fitness (balance test SBT) did not show a statistically significant improvement in results. A statistically significant improvement in results was recorded in other physical fitness tests, as well as in team sports polygons and questionnaires for determining the level of quality of life.

Similar results can be seen in the eighth grade students (Table 3). Statistically significant improvements were recorded in all parameters in boys, while in girls only in the SBT there was no statistically significant difference.

Discussion

Assuming that there is a positive impact of the physical education program on the psycho-physical development of children, the aim of this research was to determine the impact of that program over a semester on physical fitness, sports-specific skills and the quality of life of elementary school students. The results showed a statistically significant improvement in scores on most physical fitness tests. Statistically significant progress was recorded in the fields of both team sports, as well as in the level of quality of life for both boys and girls in both grades. This outcome is also suggested by earlier views of experts that the physical education program has the potential to significantly contribute to the physical, life, social and cognitive development of children. This program particularly affects the development of children's basic movement skills and physical competencies that are necessary for the development of sports activities, and can also support the development of social skills and social behavior, self-esteem and attitudes at school, and in certain circumstances, academic and cognitive development (Bailey, 2006).

The findings obtained in this study indicate that the physical education program in the field of developing physical fitness and soccer and basketball skills, with its contents, had a positive effect on the largest number of parameters of physical fitness, except for balance (SBT) of the seventh-grade boys ($p = 0.113$) and eighth-grade girls ($p = 0.075$), as well as the skills of both team sports. Kriemler et al. (2010) also found that school physical education, which was composed of several teaching contents, improved the level of physical activity (0.44, 0.05 to 0.82; $p = 0.03$) and aerobic capacity (0.17, 0.01 to 0.32; $p = 0.04$). A similar nine-month study was conducted by Meyer et al. (2014) who, after completing a complex physical education program, observed beneficial effects in aerobic capacity (0.373 z-score units [95%-CI: 0.157 to 0.59, $p = 0.001$]). A physical education

program also develops students' cardio-respiratory fitness, but it is also suggested to be combined with other approaches to further increase the impact it can have on increasing physical fitness and physical activity in general (Young, Phillips, Yu & Haythornthwaite, 2006). School programs for the improvement of physical education can improve physical fitness as reflected by maximal oxygen uptake (VO_2max) (MD 1.19 mL/kg/min, 95% CI 0.57 to 1.82) (Neil-Sztramko, Caldwell & Dobbins, 2021), and also can statistically significantly improve muscle strength ($p < 0.001$), general strength ($p < 0.001$), cardiorespiratory fitness ($p < 0.001$), flexibility ($p = 0.005$) and overall health-related fitness score ($p = 0.001$) (Lee, So, Youn & Kim, 2021). School upbringing and education through soccer exercises improves the level of physical activity and psychological well-being, both in girls and in boys who from moderately to highly rate the level of enjoyment in this kind of sports activity (Larsen et al., 2021). A school soccer program improves various parameters of physical fitness (Larsen et al., 2023). Learning basketball skills in the physical education program can be done using a technical and tactical approach based on the level of physical fitness of the students. Both approaches in the physical education program can improve the results of learning basketball skills, so that a tactical approach is recommended for students with good physical fitness, while a technical learning approach is preferred for students with low physical fitness (Nur & Malik, 2021). The basketball program at school also helps in improving the motor efficiency of obese children (Elsayed, 2014). Team sports, including basketball and soccer in the physical education program, improve certain parameters of physical fitness such as balance ($p < 0.050$) and jumping abilities ($p < 0.050$) (Larsen et al., 2018).

The results of this research indicate that the physical education program has a positive effect on improving the quality of life of children. Both boys and girls of both grades (seventh grade boys $p < 0.001$; seventh grade girls $p < 0.001$; eighth grade boys $p < 0.001$; eighth grade girls $p < 0.001$) recorded a statistically significant change in the level of quality of life. These statements are also confirmed by other researches (Wu et al., 2017; Wunsch et al., 2021). The school-based physical education program ("Active School") shows positive effects on children's psychological well-being, social support and the school environment (Kvalø & Natlandsmyr, 2021). Physical education programs can reduce anxiety, increase resilience, improve well-being and increase positive mental health in children and adolescents. Therefore, taking into account the positive effects of physical education on health in general, it is suggested to increase the fund of physical education classes (Andermo et al., 2020). Also, it should be noted that there is a cause and effect relationship between attitudes towards physical activity and the level of participation in the activity itself. In this regard, it is considered that children with more positive attitudes towards physical activity participate more often in physical activity outside of school and show greater amounts of physical activity than those with less positive attitudes. Fostering children's positive attitudes towards physical activity is suitable for the promotion of children's current and later participation in physical activity (Zeng, Hipscher & Leung, 2011).

However, there are also studies conducted in schools in which minor effects of physical education on the overall quality of life were obtained. Hartmann, Zahner, Pühse, Puder and Kriemler (2010) found that the school physical education program did not affect the physical quality of life of the first-grade students and the physical and psychosocial quality of life of the fifth-grade students but that intervention had a positive impact on the psychosocial quality of life of the first-grade students. However, the overall impact of the school-based physical education program on the quality of life of elementary school children is low. Some researchers did not record any statistically significant changes in the quality of life of students after the implementation of the school-based physical education program (Kriemler et al., 2010).

This study is also subject to some limitations and shortcomings. Firstly, a larger sample of children covering a wider population from different geographic areas would likely yield much more accurate data. Secondly, a larger number of tests would complete the picture of students' physical fitness. Thirdly, there are licensed questionnaires for the assessment of the quality of life that are also filled out by parents, so they provide additional information about the condition and level of the quality of life of their children. Fourth, the fact that the program was not conducted by the same teacher in different schools can also be a drawback. On the other hand, if the sample were larger, it would not be physically possible for the same teacher to carry out the programs in all schools. Fifth, the time for monitoring the physical education program and determining its impact can be longer, e.g. the whole school year.

Conclusion

The school-based physical education program is an important factor for the development and improvement of the psycho-physical status of students. The very fact that this school program can be the only organized implementation of physical exercise for children who do not actively play any sport, that is, are not members of sports clubs, indicates the importance of this program and its professional organization. In today's sedentary lifestyle that affects both children and adolescents, every successful attempt to physically activate and engage in some form of physical exercise according to a professionally organized and guided program contributes to a better psycho-physical and health status. The habit of exercising that is formed in childhood and adolescence remains in the later years of life. Therefore, it is necessary to frequently evaluate this process in an attempt to improve it as much as possible.

The aim of this research was to determine the impact of the physical education program over a semester on motor performance, sport-specific skills and the quality of life of elementary school students, and it was shown that the program had a positive effect on most of the examined parameters, so the initial assumption was not rejected. The results show that the physical education program is, first of all, well designed and varied, and then also well organized and implemented. With the professional work of teachers and the engagement of students, it is possible to influence the increase in physical activity and the improvement of the psycho-physical status of students. However, given all the shortcomings, the results of this study should be interpreted with caution regardless of the acceptable risk of bias. In any case, longer-term research into such impacts is needed.

Conflict of interest

The authors did not receive support from any organization for the submitted work. The authors have no relevant financial or non-financial interests to disclose.

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Вплив занять фізичною культурою протягом семестру на психофізичний розвиток учнів початкової школи

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 8 с., 3 табл., 2 рис., 50 джерел.

Мета дослідження. Метою цього дослідження було визначити вплив програми фізичного виховання протягом семестру на фізичну підготовленість, специфічні спортивні навички (футбол і баскетбол) та якість життя учнів початкової школи (7 та 8 клас).

Матеріали та методи. У дослідженні взяли участь 128 учнів (64 хлопчики та 64 дівчинки) з трьох початкових шкіл віком 13-14 років. Для оцінки фізичної підготовленості використовували батарею з п'яти діагностичних тестів: Модифікований тест на спритність «Т», Іллінойський тест на спритність, тест «човниковий біг 10×5», тест на рівновагу в положенні стоячи та 2-хвилинний тест крокування на місці. Для оцінки навичок гри у футбол та баскетбол використовувалися тренувальні полігони з використанням елементів спортивних ігор. Визначення рівня якості життя проводилося за допомогою педіатричного опитувальника якості життя (Pediatric Quality of Life Inventory TM – PedsQL).

Результати. Проведене дослідження встановило статистично значуще покращення результатів більшості тестів для визначення фізичної підготовленості у виконанні всіх командних видів спорту на тренувальних полігонах, а також рівня якості життя як для хлопчиків, так і для дівчаток в обох класах.

Висновок. Можна зробити висновок, що програма з фізичної культури була добре організована та реалізована, що позитивно вплинуло на покращення психофізичного стану учнів.

Ключові слова: фізична підготовленість, якість життя, діти, футбол, баскетбол.

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The Effect of Hypoxic Exercise Combined with Crocodile Blood Supplementation on Aerobic Capacity and Hematological Variables in Athletes

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Abstract

Study purpose. This study aimed to compare the effects of hypoxic exercise combined with crocodile blood supplementation on hematological and maximum oxygen consumption parameters in soccer players.

Materials and methods. This study included 39 male soccer players aged 21.69 ± 1.98 years who were randomized to three groups. All groups performed the same training program, which comprised treadmill exercise at 70%–75% of maximum heart rate for 7 weeks with sessions of 30 min/day and 3 days per week. The first group was the control placebo group (CG, n = 13), the second group received one capsule per day (60 mg) of a freeze-dried crocodile blood supplement (SUP, n = 13), and the third group received the freeze-dried crocodile blood supplement and performed the training program under hypoxic conditions (H-SUP, n = 13, FiO_2 = 16.3%). A hematological evaluation was conducted and maximal oxygen uptake (VO_2max) was measured using the Bruce protocol treadmill test.

Results. The H-SUP group demonstrated significantly higher erythropoietin (EPO) levels (14.40 ± 2.41 mIU/mL) compared to the SUP group (11.50 ± 2.08 mIU/mL) and CG (12.01 mIU/mL) after the intervention. From pre- to post-intervention, VO_2max significantly increased in the H-SUP (Pre: 45.63 ± 4.75, Post: 49.33 ± 5.81) and SUP groups (Pre: 44.59 ± 4.75, Post: 47.30 ± 5.68) but not in the CG.

Conclusions. This study reveals that a combination of freeze-dried crocodile blood supplementation and hypoxic exercise causes hematological alterations, particularly the activation of EPO secretion, and increases VO_2max in soccer players.

Keywords: crocodile blood supplement, hematological, aerobic capacity, hypoxic training, amateur male soccer player.

Introduction

Hypoxia and physical exercise are two distinct and powerful metabolic stressors that cause molecular alterations and changes in oxygen supply and utilization throughout the body. Physical training in hypoxic conditions is thus commonly employed to improve athlete aerobic performance by combining the benefits of both stimuli to elicit peripheral adaptations (Ponsot et al., 2006). Systematically reducing PO_2 during the training process may trigger various biochemical and structural changes in skeletal muscle that favor oxidative processes (Czuba et al., 2011). According to one concept, hypoxic exposure during training (intermittent hypoxic training; IHT) may stimulate serum erythropoietin (EPO) synthesis, which increases erythrocyte count and enhances oxygen supply to the working muscles (Powell & Garcia, 2000). Unfortunately, the findings of several previous studies have not supported this hypothesis (Katayama et al., 2004; Roels et al., 2005). However, Hamlin et al. (2010) reported an increase in hemoglobin (Hb) concentration and hematocrit (Hct) value after IHT in their most recent study. These hematological adaptations that occur in response to hypoxia

are primarily responsible for the beneficial effects of altitude training on sea-level performance. In addition to potentially improving endurance performance, IHE and IHT may benefit anaerobic exercise performance (Bonetti et al., 2006; Hendriksen & Meeuwsen, 2003), possibly via increases in muscle buffering capacity (Gore et al., 2001) and glycolytic enzyme activity (Katayama et al., 2004). Variables that have been identified as affecting these physiological responses include erythropoietic response, ventilatory limitations, genetic factors, and hypoxic dose.

Iron is a major substrate required in the synthesis of heme as well as mitochondrial iron-dependent proteins (Gupta, 2014). The effects of iron deficiency on human endurance performance are well known. After iron-depleted female athletes with mild anemia, a decrease in post VO_2max (Schoene et al., 1983). It is thus typically recommended that athletes ingest a daily oral iron supplement to facilitate altitude adaptations and maintain iron balance. The exact role of iron in the hematological and non-hematological response to hypoxia has not been investigated in detail thus far. Some studies have shown that iron supplementation during altitude training improves Hb mass (Govus et al., 2015; Ryan et al., 2014) while others have found that Hb mass does not increase with supplementation during altitude training (Friedmann et al., 1999). This inconsistency in the existing evidence makes it difficult to reach a consensus on the appropriate iron status and supplementation regimen to employ during altitude training.

While cutoff values have been defined for Hb and serum ferritin levels beyond which iron supplementation is recommended in athletes undergoing training at sea level (Nielsen & Nachtigall, 1998), there are currently no clear guidelines on iron supplementation practices during altitude training. Given the conflicting findings regarding the need for supplementation at altitude and the absence of proper recommendations, the role of iron during high-altitude training requires further investigation (T. D. P. Nandadeva et al., 2019).

The Thailand Food and Drug Administration has approved crocodile blood products as a dietary supplement for human consumption at a maximum allowance level of 1 g per day (Chaeychomsri et al., 2013). One study found that an 18-day supplementation regimen of crocodile blood (1 g day-1) aids in the maintenance of functional performance and prevention of muscle swelling after exercise (Paratthakonkun et al., 2021). Blood from crocodilians has notably lower concentrations of copper, iron, and zinc compared with human and pig blood. Despite the substantial difference in iron content between fresh crocodilian and pig blood, the iron content of freeze-dried crocodile blood (164 mg/100 g) has been reported to be similar to that of freeze-dried pig (149.01 ± 3.81 mg/100 g) and chicken (181.66 ± 1.01 mg/100 g) blood (Chook et al., 2021). No studies have evaluated changes in hematological response and aerobic capacity with freeze-dried crocodile blood supplementation combined with hypoxic training. Hence, the aim of the study was to compare the effects of hypoxic exercise combined with crocodile blood supplementation on hematological and maximum oxygen consumption parameters in soccer players.

Materials and methods

Study participants

Thirty-nine male soccer players (mean age ± standard deviation [SD], 21.7 ± 1.9 years) were recruited to participate in this study. The players were recruited from the local university soccer team and represented typical club-level players. All players were free from injury, had lived at sea level for the previous 6 months, had no history of severe acute mountain sickness or contraindicative health conditions, and were not undergoing any medication regimens (e.g., anabolic steroids, creatine, sympathoadrenal drugs) during the study. All players were in their preseason training phase and typically completed 5–6 training sessions per week, which included soccer-specific and conditioning sessions. All players underwent training at the same time at low altitude (67 m above sea level in the Uttaradit province). Ethical approval was obtained from the Research Ethics Committee of Uttaradit Rajabhat University (reference COA No. 020/2020). Informed written consent was obtained from each participant prior to the beginning of the study.

Freeze-dried crocodile blood preparation

Crocodile blood supplementation (CB) was produced from Siamese crocodile (Crocodylus siamensis) by C S G Products (THAILAND) Co. Ltd., under Good Manufacturing Practice (GMP) and Hazard Analysis Critical Control Point (HACCP) certification scheme for processing and safety management which has subsequently approved by the Food and Drug Administration (FDA) of Thailand, Ministry of Public Health, as a dietary supplement (Chaeychomsri et al., 2013). Both male and female healthy crocodiles were selected for the CB production procedures, which included collecting blood samples in an antiseptic environment, pasteurizing, and lyophilizing the samples before freeze-drying the CB and putting them in capsule form.

Study organization

This study was a randomized controlled trial comparing changes in hematological parameters and VO_2max after 7 weeks of training. The participants were randomly divided into three experimental groups: a control placebo group (CG, n = 13), a group who consumed one capsule per day (60 mg) of supplemental freeze-dried crocodile blood (SUP, n = 13), and another group who consumed one capsule per day of supplemental freeze-dried crocodile blood (H-SUP, n = 13). The training program employed during the study was the same for all groups and consisted of treadmill exercise at 70%–75% of maximum heart rate. The total experimental period was 30 min/day, 3 days/week, every Monday, Wednesday, and Friday. The CG and SUP groups exercised while breathing room air and the H-SUP group exercised while breathing air with a 16.3% oxygen concentration (hypoxic condition), as shown in Figure 1. The hypoxic condition was generated using a hypoxicator machine (ATS-HP–Hyperoxic; Altitude Technology Solutions Co., Ltd. [ATS], Australia).

Measures

Hematological parameters

A 10 mL blood samples were drawn by medical technologist from the players' median cubital vein while they were seated and resting for 5 minutes on the day before commencing (PRE) and 4 days after ending (POST)

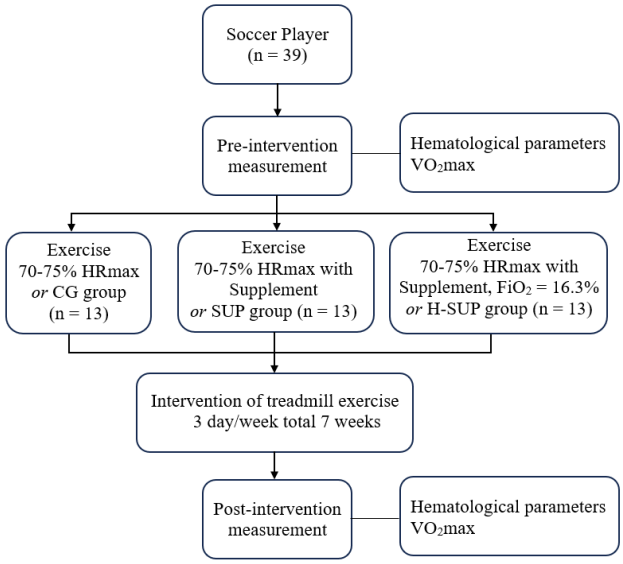

Fig 1. Outline of training and testing schedule

the intervention period. The participants were instructed to refrain from engaging in strenuous physical activity for 24 hours prior to testing. The blood samples were immediately stored on ice, transported to the Fort Pichaidaphak Hospital, and analyzed for red blood cell (RBC) count, Hct, and Hb and EPO concentrations. All blood samples were taken during the morning hours.

Measurement of VO_2max

VO_2max testing was performed using the Bruce protocol, which consists of graded exercise on a treadmill, with speed and elevation increasing every 3 minutes until the player can no longer continue the test. Once all equipment was set up, the test began with the treadmill set at a speed of 1.7 miles per hour and incline of 10%. Every 3 minutes, the speed and incline increased by 10%. After each stage, the players were asked if they were able to continue, and a thumbs-up signal indicated that they could continue while a thumbs-down signal indicated that the test should be stopped. When participants felt that they could only continue for another 10–15 seconds, they waved their hand and gave a thumbs-down signal to terminate the test.

Heart rate and SpO_2 monitoring

In all groups, heart rate and oxygen saturation were monitored daily before and during treadmill exercise using a Polar heart rate monitor (model: V800) and pulse oximeter (Beurer model: PO30, USA), respectively.

Statistical analysis

The values were expressed as means ± SD. All data were tested for normal distribution using the Kolmogorov–Smirnov statistic. Differences between baseline measures were assessed by performing a one-way analysis of variance (ANOVA). As the sample sizes were unequal, the Bonferroni post hoc test was employed for pairwise comparisons when one-way ANOVA results showed a significant difference between groups. A p-value of less than 0.05 was considered statistically significant.

Results

The baseline characteristics of the CG, SUP, and H-SUP groups are presented in Table 1. There were no significant differences in mean age, weight, height, body mass index, VO_2max, or blood parameters between the three groups, indicating that the athletes in all groups had similar baseline anthropometric, aerobic performance, and blood parameter measures.

The hematological evaluation performed before and after the 7-week intervention period consisted of RBC count, Hct, and Hb and EPO concentrations, as presented in Table 2. Subgroup analysis, delineating participants based on experimental group, revealed no statistically significant differences in RBC, Hb, or Hct in all groups from PRE to POST. A statistically significant difference was observed only in EPO concentrations ($p < 0.05$), which significantly increased in the SUP and H-SUP groups from PRE to POST. In the between-group comparison of POST hematological parameters, a significant difference was only found in EPO concentration between the H-SUP group (14.4 ± 2.4 mIU/mL) and the CG (12.0 ± 2.2 mIU/mL), as illustrated in Figure 2.

Table 1. Comparison of baseline parameters between the three groups

Parameters	CG (n = 13)	SUP (n = 13)	H-SUP (n = 13)	One-way ANOVA	
				F	p-value
Age (y)	22.00 ± 1.29	21.69 ± 1.25	21.38 ± 3.01	0.300	0.743
Weight (kg)	68.00 ± 5.22	69.00 ± 3.65	68.46 ± 3.01	0.142	0.868
Height (cm)	172.69 ± 4.83	173.07 ± 4.73	173.92 ± 6.13	0.185	0.832
BMI (kg/m^2)	22.77 ± 0.94	23.04 ± 1.02	22.60 ± 0.97	0.644	0.531
VO_2max (mL/kg/min)	45.10 ± 5.05	44.59 ± 4.75	45.63 ± 4.75	0.151	0.861
RBC (106/μL)	5.54 ± 0.52	5.38 ± 0.43	5.24 ± 0.32	1.520	0.232
Hemoglobin (g/dL)	14.69 ±1.01	14.87 ± 0.78	15.37 ± 0.66	2.351	0.110
Hematocrit (%)	44.92 ± 1.68	45.00 ± 1.35	45.68 ± 1.26	1.083	0.349
EPO (mIU/mL)	11.23 ± 3.57	10.37 ± 2.06	11.46 ± 1.78	0.636	0.535

The data presented are means ± standard deviation. CG, control group; SUP, supplement group; H-SUP, supplement with hypoxic training group; BMI, body mass index; VO_2max, maximal oxygen consumption; RBC, red blood cell; EPO, erythropoietin

Table 2. Comparison of pre-intervention and post-intervention hematological parameters within the three groups

		RBC (106/μL)	Hb (g/dL)	Hct (%)	EPO (mIU/mL)
CG	Pretest	5.54 ± 0.52	14.69 ± 1.01	44.92 ± 1.68	11.23 ± 3.57
	Posttest	5.62 ± 0.72	14.60 ± 1.22	45.23 ± 1.50	12.01 ± 2.25
	95% CI	-0.31 to 0.16	-0.79 to 0.97	-1.85 to 1.22	-1.92 to 0.35
	p-value	0.501	0.824	0.663	0.159
SUP	Pretest	5.38 ± 0.43	14.87 ± 0.78	45.00 ± 1.35	10.37 ± 2.06
	Posttest	5.41 ± 0.56	14.92 ± 0.94	45.25 ± 1.05	11.50 ± 2.08*
	95% CI	-0.46 to 0.40	-0.45 to 0.36	-0.74 to 0.24	-2.12 to -0.12
	p-value	0.886	0.711	0.300	0.031
H-SUP	Pretest	5.24 ± 0.32	15.37 ± 0.66	45.68 ± 1.26	11.46 ± 1.78
	Posttest	5.40 ± 0.33	15.40 ± 0.77	45.94 ± 1.38	14.40 ± 2.41*
	95% CI	-0.41 to 0.11	-0.12 to 0.25	-01.32 to 0.80	-4.15 to -1.70
	p-value	0.234	0.858	0.603	0.001

The data presented are means ± standard deviation. *p < 0.05 for pretest to posttest comparisons. CG, control group; SUP, supplement group; H-SUP, supplement with hypoxic training group; RBC, red blood cell; Hb, hemoglobin; Hct, hematocrit; EPO, erythropoietin

In the CG, mean PRE VO_2max was 45.1 ± 5.1 mL/kg/min and POST VO_2max was 44.8 ± 4.3 mL/kg/min; in the SUP group, PRE VO_2max was 45.6 ± 4.7 mL/kg/min and POST VO_2max was 49.3 ± 5.8 mL/kg/min; and in the H-SUP group, PRE VO_2max was 44.6 ± 4.8 mL/kg/min and POST VO_2max was 47.3 ± 5.7 mL/kg/min (Figure 3a). Compared to baseline, the percent change in VO_2max in the CG, SUP, and H-SUP groups was -0.5% ± 3.4%, 6.1% ± 5.8%, and 8.0% ± 5.1%, respectively. There was a significant increase in VO_2max in the SUP and H-SUP groups. Univariate ANOVA accompanied by post hoc pairwise comparisons revealed that the SUP and H-SUP groups had significantly larger percent changes in VO_2max compared to the CG following the 7-week intervention (Figure 3b).

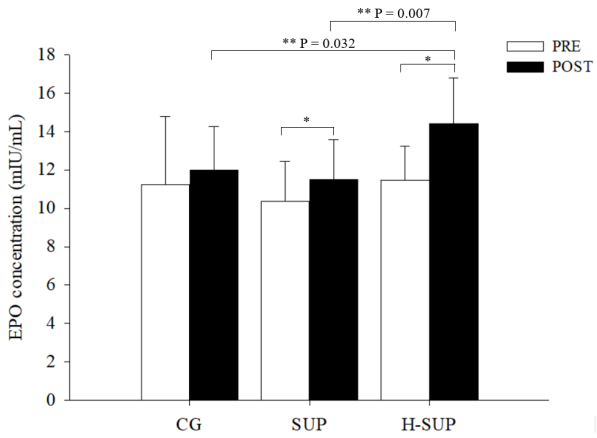

Fig 2. Changes in erythropoietin (EPO) concentration before (PRE) and after (POST) the 7-week intervention. The data presented are means ± standard deviation. *p < 0.05 (PRE vs POST), **p < 0.05 (POST between-group comparison)

Discussion

This was the first study to investigate the effects of a freeze-dried crocodile blood supplement combined with hypoxic training conditions on soccer players. The primary findings of the study were taken after 7 weeks of aerobic exercise training. Endurance performance as measured by VO_2max and EPO concentration improved in the groups receiving supplementation and supplementation in combination with hypoxic training compared to the control group, and it appears that supplementation with hypoxic training

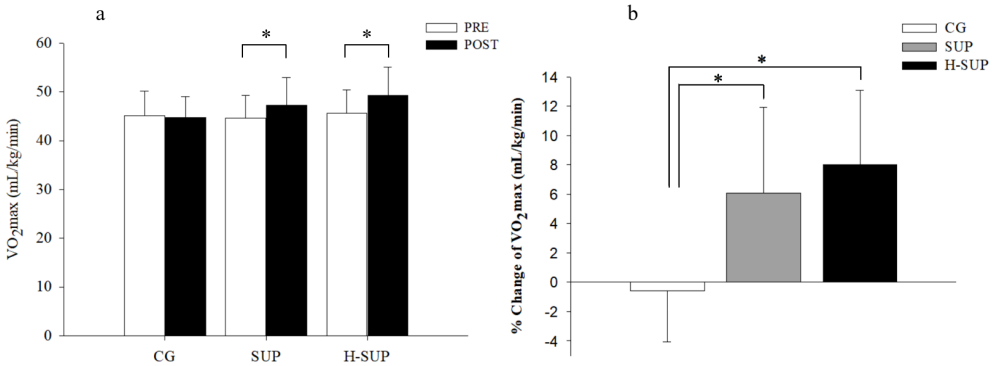

Fig 3. a) Changes in maximal oxygen consumption (VO_2max) before (PRE) and after (POST) the 7-week intervention. b) Comparison of percent change in VO_2max between groups after the 7-week intervention. Values are presented as means ± standard deviation. *p < 0.05

conditions may be slightly better than supplementation with normoxic training conditions.

An absolute increase in VO_2max of 6%–8% was observed in both groups receiving crocodile blood supplementation. In contrast, players in the non-supplement and normoxic training group did not demonstrate a significant change in VO_2max. These results suggest that the increase in VO_2max in the supplement groups was due to the freeze-dried crocodile blood supplement, which has micronutrients, particularly iron, that are essential for numerous functions related to physical activity and exercise. The International Olympic Committee recommends that female athletes have iron deficiency screenings to optimize performance (Ljungqvist et al., 2009). In addition, several studies have found that taking 100 mg of iron per day combined with 8 weeks of aerobic exercise increases VO_2max when compared to a control condition. VO_2max values in one such study were 41.7 ± 1.0 mL/kg/min in the iron supplement group and 39.4 ± 2.0 mL/kg/min in the control group. A significant decrease in lactate was additionally observed in the iron-supplemented group after an endurance test compared with the control group (LaManca & Haymes, 1993). Researchers have reported decreased time to exhaustion during submaximal and maximal work in nonanemic, iron-deficient groups. Increases in submaximal endurance were associated with improvements in iron-dependent oxidative enzyme capacity within muscles, and the enzyme increases in turn were correlated with improved iron stores. Both time to exhaustion during endurance activities and enzyme activity continued to improve with iron repletion after hemoglobin concentration and VO_2max were returned to normal in iron-depleted rats (Davies et al., 1984; Davies et al., 1982). Moreover, Schumacher and colleagues compared the blood markers of iron status among various male athlete groups and found a marker in endurance runners, in contrast to endurance cyclists, that suggested that runners may experience more hemolysis due to foot impact (Schumacher et al., 2002). However, supplementation demonstrated no significant effect on post-test lactate (Klingshirn et al., 1992). The discrepancy in findings between the two studies may be attributed to differences in participants' initial iron status. In addition, the study showed a single-time oral treatment of crocodile blood supplement that upregulated the anti-oxidative enzymes catalase and superoxide dismutase (Chook et al., 2021) may lead to an adaptive response resulting in increased resistance to oxidative stress, which is related to the relationship between VO2 and TNF-α inflammation in the exercising muscles (Rosado-Perez & Mendoza-Nunez, 2018). Another possible explanation for the lack of supplementation effect on lactate in the time trial is the large training effect observed in the study, which may have obscured any supplementation effect. Although hemoglobin is known as a chemical buffering system which may cause improvement in lactic acid levels in the bloodstream or metabolic acidosis resulting from exercise. However, hemoglobin from crocodile may have different characteristic compare to human hemoglobin, which less information to confirm the effective dose and the duration of the supplement.

The increase in EPO found in the SUP and H-SUP groups in this study is in accordance with previous findings confirming the stimulatory effect of iron supplementation on erythropoiesis (T. D. P. Nandadeva et al., 2019). Interestingly, in the present study the players who received supplementation while training in hypoxic conditions demonstrated a higher EPO concentration than both the CG and SUP groups. The mechanism underlying this result may relate to renal oxygen supply, as the kidney is a highly sensitive oxygen sensor that plays a key function in modulating RBC formation in hypoxic conditions. The identification of EPO, which is required for normal erythropoiesis, and the purification of hypoxia-inducible factor, the transcription factor that regulates EPO synthesis and mediates the cellular adaptation to hypoxia, have both contributed to a better understanding of the molecular basis of oxygen-regulated erythropoiesis (Haase, 2010). Along these lines, Eckardt et al. found a significant increase in EPO after 5 hours of intermittent hypoxia exposure per day at an altitude of 3000–4000 meters (Friedmann et al., 1999). A study conducted on triathletes found contradictory results as in the present study increases in erythrocytes and EPO after intermittent hypoxic training (Ramos-Campo et al., 2015). Moreover, data have shown that 8 weeks of low-altitude (825 meters above sea level) training, supplemented with regular bouts of intermittent hypoxic training at higher altitudes, produced beneficial performance improvements and increases in EPO levels in soccer players (Wonnabussapawich et al., 2017).

Conclusions

The most important finding of this work is the increased VO_2max and EPO levels found in soccer players receiving 7 weeks of freeze-dried crocodile blood supplementation with both normoxic and hypoxic (16.3% FiO_2) training conditions compared to those receiving no supplementation and training in normoxic conditions. These results suggest that a freeze-dried crocodile blood supplement with hypoxic exercise conditions is an effective strategy to improve aerobic capacity and hematological parameters in soccer players.

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Conflict of interest

The authors guarantee that no conflicts of interest exist.

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Вплив гіпоксичного тренування у комбінації з додаванням до раціону крокодилячої крові на аеробну продуктивність та гематологічні показники у спортсменів

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів
Реферат. Стаття: 7 с., 2 табл., 3 рис., 29 джерел.

Мета дослідження. Метою цього дослідження було вивчити вплив додавання до раціону крокодилячої крові в поєднанні з гіпоксичним тренуванням на рівень споживання кисню та гематологічні показники у футболістів.

Матеріали та методи. У дослідженні взяли участь 39 футболістів-чоловіків віком 21,69 ± 1,98 року, які були рандомізовані на три групи. Усі групи виконували ідентичну тренувальну програму, яка включала тренування на біговій доріжці з рівнем 70%-75% максимальної частоти серцевих скорочень протягом 7 тижнів із заняттями тривалістю 30 хв/день та 3 дні на тиждень. Перша група була контрольною групою, яка вживала плацебо (КГ, n = 13), друга група отримувала одну капсулу на день (60 мг) сублімованої добавки з крокодилячої крові (ДОБ, n = 13), а третя група отримувала сублімовану добавку з крокодилячої крові та виконувала тренувальну програму в умовах гіпоксії (Г-ДОБ, n = 13, FiO_2 = 16,3%). Було проведено гематологічну оцінку та визначено показник максимального споживання кисню (VO2max) за допомогою тредміл-тесту (тест на біговій доріжці) за протоколом Брюса.

Результати. Досліджувана група (Г-ДОБ), що отримувала сублімовану добавку з крокодилячої крові та виконувала тренувальну програму в умовах гіпоксії, показала значно вищі рівні еритропоетину (ЕПО) (14,40 ± 2,41 мМО/мл) порівняно з групою (ДОБ), яка отримувала одну капсулу на день (60 мг) сублімованої добавки з крокодилячої крові (11,50 ± 2,08 мМО/мл) та КГ (12,01 мМО/мл) після проведення інтервенції. Від початку до моменту завершення інтервенції спостерігалося суттєве збільшення показника VO_2max у групах Г-ДОБ (до: 45,63 ± 4,75, після: 49,33 ± 5,81) та ДОБ (до: 44,59 ± 4,75, після: 47,30 ± 5,68), але не в КГ.

Висновки. Це дослідження доводить, що поєднання прийому сублімованих добавок з крокодилячої крові та проведення гіпоксичних тренувань викликає гематологічні зміни, зокрема активацію секреції ЕПО, та збільшує показник VO_2max у футболістів.

Ключові слова: добавка з крокодилячої крові, гематологічний, аеробна продуктивність, гіпоксичне тренування, футболіст-аматор.

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Stepping Towards Better Health: The Effects of Walking Football for 12 Weeks on Cardiovascular Health in Hypertensive Male Senior Citizens

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Abstract

Background. The study deals with cardiovascular concerns in hypertensive elderly males, evaluating the effectiveness of a walking football program for targeted health improvement in this population.

Study purpose. This study aims to clarify and characterize changes in cardiovascular health due to a 12-week walking football training program in male seniors (60-70 years) with hypertension.

Materials and methods. This study engaged 60 hypertensive males aged 60 to 70 years from diverse regions of Kashmir, India. Purposive sampling was used to select individuals who hadn't participated in physical activities for a period of six months. In addition, participants were divided into two groups: experimental and control. The study's design and objectives were explained to participants one week before testing. Baseline data was collected a week prior to the 12-week program. The experimental group attended thrice-weekly, 1-hour walking football sessions consisted of 10-minute warm-up, 45-minute game, and 5 minute cool-down. Assessments were conducted at the end of the 4th, 8t^{h}, and 12th weeks. To analyze the data, a 2 (group: experimental, and control) × 4 (time: baseline, 4th week, 8th week, and 12th week) mixed ANOVA was conducted.

Results. During the study, the control group showed a slight decrease in systolic blood pressure (SBP) by week 8, which returned to baseline levels by week 12. Conversely, the experimental group demonstrated a consistent decline in systolic (SBP) and diastolic blood pressure (DBP), as well as resting heart rate (RHR), with a significant decrease observed by week 12. Additionally, basal metabolic rate (BMR) steadily increased in the experimental group over the 12 weeks. On the other hand, there were no significant changes in DBP, RHR, or BMR throughout the duration of the training program in the control group.

Conclusions. Walking football has been shown to be beneficial for hypertension, highlighting its public health potential. The study confirms its positive integration into physical activities aimed at ensuring the community well-being.

Keywords: basal metabolic rate, diastolic blood pressure, hypertension, resting heart rate, senior citizens, systolic blood pressure, walking football.

Introduction

Regular physical activity stands out as a simple yet powerful strategy for individuals and communities to mitigate the risk of cardiovascular disease (Lear & Yusuf, 2017). In the Indian population, cardiovascular disease is remarkably common and is frequently associated with age (Devi et al., 2013). The third most important risk factor in South Asia that increases the burden of cardiovascular disease is hypertension (Lim et al., 2012). The healthcare infrastructure and cardiovascular health of India face considerable strain due to the prevalence of hypertension (Reddy et al., 2005).

In India, 57% of deaths from stroke and 24% from coronary heart disease are directly connected to hypertension (Gupta, 2004). Rural areas harbor hypertension in about 25% of the population, while urban areas see a prevalence of 33% (Anchala et al., 2014). Looking globally, data from 2005 revealed that hypertension was diagnosed in 20.6% of Indian men and 20.9% of Indian women. Projections indicate that by 2025, these figures will escalate to 22.9% for men and 23.6% for women (Kearney et al., 2005).

As individuals progress in age, their blood pressure tends to increase. This rise is attributed to the escalating arterial stiffness, causing a continuous elevation in systolic blood pressure over adulthood, while diastolic blood pressure reaches its zenith in the sixth decade before gradually diminishing. Consequently, as people grow older, their pulse pressure tends to widen (Kannel et al., 1981). Incorporating exercise into one's lifestyle emerges as a pivotal strategy for averting, addressing, and controlling hypertension. Engaging in exercise regimens primarily emphasizing endurance activities enables adults to sidestep hypertension development and maintain lower blood pressure levels.

Individuals diagnosed with hypertension experience the most significant reduction in blood pressure through endurance exercise, whether it's during a single exercise session (acute) or over a period of exercise training (chronic). Typically, blood pressure decreases by approximately 5-7 mm Hg after either type of exercise. Notably, after engaging in endurance exercise, blood pressure can remain lowered for up to 22 hours, a phenomenon termed post-exercise hypotension. The most substantial decreases are observed in individuals with initially elevated baseline blood pressure levels (Pescatello, 2004).

Consistent physical turns out to be a beneficial tactic for successfully controlling blood pressure levels. Among sports, football stands out as the most widely embraced globally. Its immense popularity could catalyze motivating individuals with hypertension to engage in exercise routines. This holds particular relevance for older adults and those with heightened health risks who have been less active in the past. A tailored training program emphasizing health and wellness benefits, while minimizing risks, might reignite interest in sports participation among many individuals. Football encompasses all essential components of a robust concept (Schrader et al., 2021).

Walking football, a rendition of the sport emerged in England in 1932 and has recently reemerged in the country, targeting individuals aged 65 and older. Its primary aim is to provide older adults with increased avenues for social engagement and physical activity. This adapted version of football, characterized by the rule of keeping one foot grounded at all times, has swiftly garnered international acclaim, particularly in regions such as Australia, North America, Europe, and Asia.

To minimize the risk of injuries, player-to-player physical contact is strictly forbidden, and there are restrictions on lifting the ball above head height. This skilled occupation is open to individuals of all genders, including those with limited mobility or medical conditions that restrict physical activity. The intensity of the game varies widely based on factors such as session duration and player age, with senior citizens and longer matches generally maintaining higher levels of intensity (Zainudin et al., 2022).Recent media coverage has increasingly highlighted the concept of walking football, emphasizing its positive impact on physical fitness and consequently, on overall health and wellbeing. Indeed, research has shown that engaging in regular exercise and physical activities like walking football can reduce mortality rates and mitigate various health-related conditions (Paffenbarger et al., 1986; Nocon et al., 2008).

While the physiological benefits of Association's football are well-documented, there remains a gap in research concerning walking football. Notably, walking football, which prohibits running, involves lower absolute physiological intensity and energy expenditure compared to traditional football.

Researching walking football training programs for senior citizens provides a valuable avenue for low-impact exercise, particularly in a demographic vulnerable to hypertension. With its 12-week duration, this program facilitates insightful observations, rendering it a focused intervention for evaluating its cardiovascular benefits among older individuals. The study's primary goal was to analyze the impact of a 12-week walking football program on the cardiovascular health of hypertensive elderly men.

Materials and Methods

Study participants

Utilizing purposive sampling, a cohort of sixty (N=60) male participants, ranging in age from 60 to 70, were selectively recruited from diverse regions of Kashmir, India for the study. These individuals were then evenly divided into two groups: experimental (n=30) and control (n=30). Inclusion criteria encompassed males with hypertension aged 60 to 70 who had refrained from engaging in any form of fitness or health-related physical activities over the preceding six months. The primary aim of the research was to evaluate the outcomes of a 12-week walking football program conducted from June to August 2022.

Study organization

To ensure clarity and understanding, participants were provided with thorough explanations of the study's design and objectives one week prior to the commencement of testing. Initial samples were collected one week before the program's initiation. The measurements of blood pressure, resting heart rate, and basal metabolic rate were conducted using specialized devices: an Omron automatic blood pressure monitor (HEM 7120) and the Omron body composition analyzer (HBF-375) respectively, at Lifeline Healthcare clinic in Srinagar, India. Participants attended the clinic in the morning, and testing was carried out during the resting phase. The reliability of the data was ensured through the confirmation of instrument reliability and the competence of testers. The study's instruments, being manufactured by reputable companies, were considered reliable.

Over the course of 12 weeks, participants in the experimental group attended a 1-hour training session thrice a week. Each session commenced with a brief 10-minute warm-up, followed by a 45-minute walking football game, concluding with a 5-minute cooling-down phase. Six teams were formed, each with five members. The sessions consisted of 5-a-side games, each lasting 20 minutes, with a 5-minute break in between. At the end of the fourth, eighth, and twelfth weeks of the walking football program, the participants were tested.

The walking football sessions were planned after consulting with all of the participants to find out what days and times would be most convenient. To monitor adherence, attendance records were maintained for each participant throughout the 12-week intervention. Additionally,

participant feedback and engagement were regularly assessed to address any concerns or modifications needed to enhance compliance.

To analyze the data, a 2 (group: experimental, and control) X 4 (Time: baseline, 4th week, 8th week, and 12th week) mixed ANOVA was conducted.

Statistical Analysis

The study employed a Mixed ANOVA alongside descriptive statistics, including Mean and Standard Deviation, to assess the impact of a twelve-week walking football program on cardiovascular health among hypertensive male senior citizens. A significance level of 0.05 was chosen. Statistical analyses, both descriptive and inferential, were conducted using the software program SPSS.

Results

This research was conducted for twelve weeks, with a 1 hour session thrice a week. The results are obtained as follows.

Table 1 displays descriptive statistics of SBP, DBP, RHR, and BMR before and after a twelve-week training period for both experimental and control groups of hypertensive senior males in Kashmir.

Before training, the mean scores for SBP in the experimental group were (147.27±6.18) and in the control group were (148.43±7.93). Similarly, the mean scores for DBP in the experimental group were (99.53±7.21) and in the control group were (98.23±6.50), for RHR in the experimental group were (79.57±9.12) and in the control group were (80.00±6.25), and for BMR in the experimental group were (1525±102) and in the control group were (1530±81).

By the fourth weekthe mean scores for SBP in the experimental group were (144.30±6.09) and in the control group were (148.23±8.35). Similarly, the mean scores for DBP in the experimental group were (96.13±5.73) and in the control group were (96.83±5.87), for RHR in the experimental group were (77.87±9.43) and in the control group were (80.20±5.05), and for BMR in the experimental group were (1532±106) and in the control group were (1529±82).

At the eighth week, the mean scores for SBP in the experimental group were (141.57±6.61) and in the control group were (145.13±7.72). Similarly, the mean scores for DBP in the experimental group were (95.03±5.57) and in the control group were (97.13±7.42), for RHR in the experimental group were (77.37±9.08) and in the control group were (80.60±5.49), and for BMR in the experimental group were (1539±106) and in the control group were (1526±83).

Finally, by the twelfth week, the mean scores for SBP in the experimental group were (140.30±6.91) and in the control group were (146.97±8.60). Similarly, the mean scores for DBP in the experimental group were (94.83±6.18) and in the control group were (97.90±5.44), for RHR in the experimental group were (76.07±9.24) and in the control group were (80.67±5.32), and for BMR in the experimental group were (1548±109) and in the control group were (1527±82).

Table 2 displayed that the design of this study merited a mixed ANOVA, with time in weeks as the within subject

Table 2. Two-way repeated measures tests of within-subjects during different weeks of walking football training between experimental and control group

Variables	Sum of squares	df	Mean square	F	p	η^2p
SBP						
Time	841	3	280.3	21.72	0.00	0.27
Time*Group	228	3	76.1	5.90	0.00	0.09
DBP						
Time	303	3	100.94	10.91	0.00	0.16
Time*Group	162	3	53.9	5.83	0.00	0.09
RHR						
Time	89	3	29.6	4.41	0.01	0.07
Time*Group	106	3	35.4	5.27	0.00	0.08
BMR						
Time	3136	2.03	1546	13.0	0.00	0.18
Time*Group	5973	2.03	1991	24.7	0.00	0.30

Table 1. Descriptive analysis on SBP, DPB, RHR and BMR during different weeks of walking football training between experimental and control group

Variables	Group	Baseline	Week 4th	Week 8th	Week 12th
SBP	Experimental	147.27±6.18	144.30±6.09	141.57±6.61	140.30±6.91
	Control	148.43±7.93	148.23±8.35	145.13±7.72	146.97±8.60
DBP	Experimental	99.53±7.21	96.13±5.73	95.03±5.57	94.83±6.18
	Control	98.23±6.50	96.83±5.87	97.13±7.42	97.90±5.44
RHR	Experimental	79.57±9.12	77.87±9.43	77.37±9.08	76.07±9.24
	Control	80.00±6.25	80.20±5.05	80.60±5.49	80.67±5.32
BMR	Experimental	1525.00±102	1532.00±106	1539.00±106	1548.00±109
	Control	1530.00±81	1529.00±82	1526.00±83	1527.00±82

Data is presented as mean± standard deviation

factor, and the intervention as the between subject factor, with a balanced sample size of 30 in each group. We ran a 2 (group: experimental, and control) × 4 (Time: baseline, 4th week, 8th week, and 12th week) Mixed ANOVA. The within subject effects analysis in SBP revealed that the time in weeks had a significant main effect, $F_{(3,28)}$ = 21.72, p=0.00, partial eta squared = 0.27. This effect however is qualified by a significant interaction between time × treatment group $F_{(3,28)}$ = 5.90, p=0.00, partial eta squared = 0.09. The within subject effects analysis in DBP revealed that the time in weeks had a significant main effect, $F_{(3,28)}$= 10.91, p=0.00, partial eta squared = 0.16. This effect is qualified by a significant interaction between time × treatment group $F_{(3,28)}$= 5.83, p=0.00, partial eta squared = 0.09. The within subject effects in RHR analysis revealed that the time in weeks had a significant main effect, $F_{(3,28)}$= 4.41, p=0.01, partial eta squared = 0.07. This effect is qualified by a significant interaction between time × treatment group $F_{(3,28)}$= 5.27, p=0.00, partial eta squared = 0.08. The within subject effects analysis in BMR revealed that the time in weeks had a significant main effect, $F_{(2.03,28)}$= 13.0, p=0.05, partial eta squared = 0.18. However, the interaction between time and treatment is significant $F_{(03,28)}$= 24.7, p=0.00, partial eta squared = 0.30.

Analysis revealed a modest main effect of groups on systolic blood pressure (SBP) ($F_{(1,58)}$ = 4.96, p=0.03, partial eta squared = 0.08). While In the control group, there is a slight decrease in systolic blood pressure by week 8th (145.13±7.72 mmHg) compared to the baseline test (148.43±8.35 mmHg). However, it subsequently increases to (146.97±8.60 mmHg) by week 12th, exhibiting no significant difference from baseline measurements. On the other hand, the experimental group demonstrates a consistent decline from baseline (147.27±6.18 mmHg) to (144.30±6.09 mmHg) at week 4th, (141.57±6.61 mmHg) at week 8th, and (140.30±6.91 mmHg) at week 12th, with a significant mean difference between groups from baseline at week 12 (Mean difference ± SE: 6.67 ± 2.02, $t_{(58)}$ = 3.31, p = 0.04). Diastolic blood pressure (DBP) showed no main effect of groups ($F_{(1,58)}$ = 0.60, p=0.44, partial eta squared = 0.01), yet the treatment group shows a continuous decline from baseline (99.53±7.21 mmHg) to (96.13±5.73 mmHg) at week 4th, (95.03±5.57 mmHg) at week 8th, and (94.83±6.18 mmHg) at week 12th. Resting heart rate (RHR) displayed no main effect of groups ($F_{(1,58)}$= 1.77, p=0.19, partial eta squared = 0.03), but the treatment group demonstrated a significant decline from pre-test (79.57 ± 9.12 bm^{-1}) to week 12 (76.07 ± 9.24 bm^{-1}). Basal Metabolic Rate (BMR) similarly showed no main effect of groups (F(1,58) = 0.10, p=0.75, partial eta squared = 0.00), yet the treatment group showed a steady increase in basal metabolic rate from baseline (1525±102 kJ) to (1539±106 kJ) at week 8th and (1548±109 kJ) at week 12th. Moreover, a notable increase is observed in the experimental group at the 8th and 12th weeks compared to the 4th week, with a further increase from the 8th to the 12th week. Conversely, in the control group, diastolic blood pressure, resting heart rate, and basal metabolic rate show no significant changes throughout the 12 weeks of the training program Table (3 and 4).

Although between-group comparisons showed no overall difference except SBP, within-subjects analysis

Table 3. Two-way repeated measures test of between-subjects during different weeks of walking football training between experimental and control group

Variables	Sum of squares	df	Mean square	F	p	η^2p
SBP						
Group	882	1	882	4.96	0.03	0.08
DBP						
Group	78	1	78	0.60	0.44	0.01
RHR						
Group	375	1	375	1.77	0.09	0.03
BMR						
Group	3674	1	3674	0.10	0.75	0.00

Table 4. Pairwise comparisons of SBP, DBP, RHR and BMR using Bonferroni post hoc test during different weeks of training

Variables	Time	Group	Time	Group	Mean diff.	SE	df	t	p
SBP	Baseline	Exp.	Baseline	Control	1.17	1.83	58	0.64	1.00
	Baseline	Exp.	Week 4th	Exp.	2.97	0.90	58	3.31	0.04
	Baseline	Exp.	Week 8th	Exp.	5.70	0.95	58	5.99	0.00
	Baseline	Exp.	Week 12th	Exp.	6.97	0.94	58	7.44	0.00
	Baseline	Control	Week 8th	Control	3.30	0.95	58	3.57	0.03
	Baseline	Control	Week 12th	Control	1.47	0.94	58	1.57	1.00
	Week 4th	Exp.	Week 12th	Exp.	4.00	1.03	58	3.89	0.01
	Week 12th	Exp.	Week 12th	Control	6.67	2.02	58	3.31	0.04
DBP	Baseline	Exp.	Week 4th	Exp.	3.40	0.74	58	4.58	0.00
	Baseline	Exp.	Week 8th	Exp.	4.50	0.74	58	6.08	0.00
	Baseline	Exp.	Week 12th	Exp.	4.70	0.87	58	5.42	0.00
RHR	Baseline	Exp.	Week 12th	Exp.	3.50	0.71	58	4.96	0.00
BMR	Baseline	Exp.	Week 8th	Exp.	14.30	2.78	58	5.15	0.00
	Baseline	Exp.	Week 12th	Exp.	23.30	3.00	58	7.75	0.00
	Week 4th	Exp.	Week 8th	Exp.	6.70	1.48	58	4.54	0.00
	Week 4th	Exp.	Week 12th	Exp.	15.70	2.22	58	7.01	0.00
	Week 8th	Exp.	Week 12th	Exp.	9.00	1.63	58	5.52	0.00

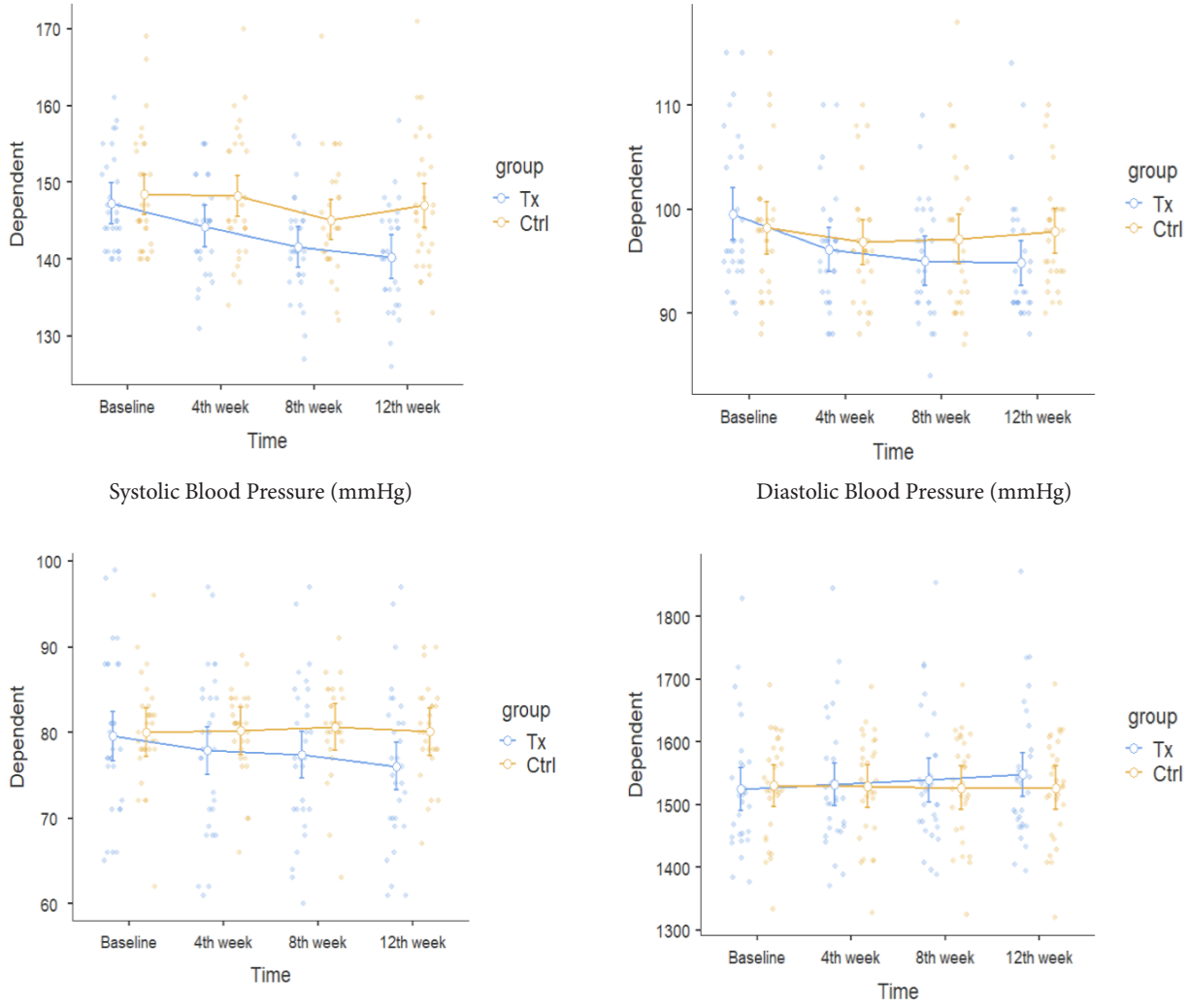

Fig. 1. Mean plots of variables in experimental (Tx) and control (Ctrl) groups

revealed the influence of both time and group allocation on outcomes, supported by significant interaction terms. These findings underscore the efficacy of the intervention in inducing favorable physiological changes over the 12-week period.

Discussion

The main objective of this research was to investigate the impact of a 12-week walking football program on the cardiovascular health of senior males diagnosed with hypertension. The results indicated positive changes in systolic and diastolic blood pressure between the participants. Numerous studies have noted a reduction in resting blood pressure among individuals having hypertension following physical activity (Biddle & Batterham, 2015; Cornelissen & Smart, 2013). Previous research has also suggested that engagement in walking football enhances overall fitness (Arnold et al., 2015), and regular walking exercises have been associated with reduced blood pressure levels (Hayashi et al., 1999; Ningsih, 2020). Health education interventions often include walking exercise as an independent nursing measure for controlling blood pressure in hypertensive patients. Additionally, studies have consistently shown reductions in risk factors for cardiovascular disease like resting blood pressure, aerobic fitness, and body composition through regular walking (Murtagh et al., 2015). Alparslan et al., (2010) carried out a study demonstrating significant decrease in systolic and diastolic blood pressure between the participants engaged in a 12-week walking program designed to manage hypertension.

There is suggestive evidence that walking may reduce heart rate and diastolic blood pressure, as indicated by a study carried out by Lee et al., (2021). Additionally, a study by Stewart et al., (2005) found that a six-month aerobic and resistance training program reduced diastolic blood pressure in elderly people with mild hypertension. Furthermore, there exists some data suggesting a moderate likelihood that walking can decrease systolic blood pressure across different age groups.

The research outcomes revealed a significant influence on the resting heart rate and basal metabolic rate of the

experimental group. Walking football positively impacted heart rate (Yüce & Saygin, 2023). Furthermore, Kammoun et al. (2022) observed a modest decrease in heart rate and a considerable improvement in heart rate variability (HRV) among middle-aged men participating in a 4-week walking football program. Additionally, Kizilay (2016) found that an 8-week run-walk training regimen led to a noteworthy and significant increase in basal metabolic rate (BMR) among sedentary women. Therefore, it is imperative to devise a comprehensive strategy that includes educational initiatives alongside walking football programs to achieve optimal outcomes.

Conclusions

In summary, the 12-week Walking Football program has demonstrated its effectiveness in improving cardiovascular health. Findings from the study indicate notable increase in basal metabolic rate and reductions in resting heart rate, diastolic blood pressure, and systolic blood pressure among participants, underscoring the significance of walking football as a health-enhancing activity. With promising results particularly tailored for male senior citizens, there is a compelling case for clubs, communities, and governmental bodies to integrate similar programs into regular schedules to promote overall well-being. This research marks a pivotal starting point, advocating for continued investigation and implementation in this domain.

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Conflicts of interest

The authors guarantee that no conflicts of interest exist.

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Крокуючи до покращення стану здоров'я: вплив занять з пішого футболу протягом 12 тижнів на здоров'я серцево-судинної системи у чоловіків похилого віку з гіпертонічною хворобою

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 8 с., 4 табл., 1 рис., 25 джерел.

Історія питання. У дослідженні розглядаються проблеми з боку серцево-судинної системи у чоловіків похилого віку з гіпертонічною хворобою, проводиться оцінка ефективності застосування програми з пішого футболу з метою цілеспрямованого покращення стану здоров'я в даній категорії населення.

Мета дослідження. Це дослідження спрямоване на визначення та надання характеристики змін у стані здоров'я серцево-судинної системи внаслідок 12-тижневої програми тренувань з пішого футболу у чоловіків похилого віку (60-70 років) з артеріальною гіпертензією.

Матеріали та методи. У дослідженні взяли участь 60 чоловіків з гіпертонічною хворобою віком від 60 до 70 років з різних регіонів Кашміру, Індія. Для відбору осіб, які не брали участі у фізичних навантаженнях протягом шести місяців, використовували метод цільової вибірки. Крім того, учасники були розділені на дві групи: експериментальну та контрольну. За тиждень до тестування учасникам пояснили план та цілі дослідження. Збір вихідних даних проводився за тиждень до початку 12-тижневої програми. Експериментальна група відвідувала заняття з пішого футболу тричі на тиждень та тривалістю 1 годину, що складалися з 10-хвилинної розминки, 45-хвилинної гри та 5-хвилинної перерви на відновлення фізичних кондицій. Оцінка показників стану здоров'я проводилася наприкінці 4-го, 8-го та 12-го тижнів. Для аналізу даних було проведено 2 (група: експериментальна та контрольна) X 4 (час: початковий рівень, 4-й тиждень, 8-й тиждень та 12-й тиждень) змішаний дисперсійний аналіз (ANOVA).

Результати. Під час дослідження в контрольній групі спостерігалося незначне зниження систолічного артеріального тиску (САТ) на 8-му тижні, яке на 12-му тижні досягло показників вихідного рівня. І навпаки, в експериментальній групі відзначалося послідовне зниження систолічного (САТ) і діастолічного артеріального тиску (ДАТ), а також частоти серцевих скорочень (ЧСС) у стані спокою, при цьому суттєве зниження спостерігалося на 12-му тижні. Також в експериментальній групі протягом 12 тижнів було зафіксовано стабільне зростання швидкості основного обміну речовин (ШООР). З іншого боку, в контрольній групі не було виявлено суттєвих змін у показниках САТ, ЧСС у стані спокою або ШООР впродовж усього періоду тренувальної програми.

Висновки. Доведено, що піший футбол є ефективним видом фізичної активності при артеріальній гіпертензії, що підкреслює його потенціал для зміцнення суспільного здоров'я. Дослідження підтверджує позитивну інтеграцію занять з пішого футболу до фізичної активності, спрямованої на забезпечення нормалізації показників стану здоров'я суспільства.

Ключові слова: швидкість основного обміну речовин, діастолічний артеріальний тиск, артеріальна гіпертензія, ЧСС у стані спокою, особи похилого віку, систолічний артеріальний тиск, піший футбол.

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Analyzing the Nutritional Awareness, Dietary Practices, Attitudes, and Performance of U-17 Football Players in Ethiopia

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Abstract

Background. Adequate nutrition knowledge is crucial for developing proper eating habits, especially among athletes, as it has a significant impact on sports performance. This underscores the consensus in sports nutrition education among professionals working with athletes.

Study purpose. The study aimed to assess the nutritional knowledge, attitudes, and dietary practices of under-17 football club players in Ethiopia.

Materials and methods. A descriptive survey research method was used, and standardized questionnaires were randomly distributed to 26 footballers to assess participants' knowledge, attitudes, and dietary practices regarding nutrition. Data were analyzed using the t-test, Pearson coefficient, and one-way ANOVA ($p < 0.05$). Reliability analysis showed a Cronbach's alpha value of 0.83 for the scales measuring attitudes towards eating habits and nutrition knowledge (0.79 and 0.78, respectively).

Results. No statistically significant differences ($p > 0.5$) were observed in the data related to eating habits, age, or nutritional understanding. Significant variations in educational backgrounds were noted ($p < 0.05$). Although gender and source were not recognized as correlates of nutritional knowledge, but age and education were.

Conclusions. In summary, the study revealed no significant differences ($p > 0.05$) in nutrition knowledge scores for age, education, and source of information. However, a significant difference ($p < 0.05$) was found between male and female athletes. Gender correlated with dietary habits, while age, education, and source of information did not. The key factor is to encourage ongoing future vision within sports organizations, nutritionists, and educational institutions to continuously refine and enhance nutrition knowledge, attitudes, and practice programs for U-17 players. It is also important to ensure sustainable relevance and effectiveness in the evolving landscape of sports and nutrition.

Keywords: attitude, dietary practice, football players, nutritional knowledge

Introduction

In contemporary athletics, the pursuit of "bigger, faster, stronger" has led to a heightened focus on optimizing performance, driving increased research in sports nutrition. Sports nutrition involves applying understanding the relationship between daily food intake and nutrition, aiming to provide energy required for exercise, support the repair and rebuilding processes, and enhance over wellness and athletic performance (Fink & Mikesky, 2015). Athletes, especially those in high-intensity training and demanding competition schedules, face musculoskeletal injury risks and performance challenges, necessitating proper dietary practices and reliable sources of nutrition-related information (Torres-McGehee et al., 2012). Ensuring optimal fueling is a fundamental requirement for athletes to achieve peak performance (Kerksick et al., 2008; Maughan & Burke, 2011). In addition to being essential for improving on-field performance, nutrition also contributes to muscle growth, injury prevention, accelerated recovery, and support for rehabilitation (Mahan & Escott-Stump, 1998). Athletes' daily dietary choices and fluid intake significantly affect their overall health, body composition, substrate availability

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during exercise, recovery, and recovery time (American Dietetic Association, 2009).

Achieving peak athletic performance is intricately tied to the strategic intake of essential nutrients (Hornstrom et al., 2011; Valliant et al., 2012). Conversely, a deficiency in nutrient supply has been identified as a potential factor leading to a discernible decrease in overall performance. Incorporating sufficient nutrition knowledge into a training program is crucial for achieving adequate nutrition. This knowledge is essential for optimizing the intake of both macronutrients and micronutrients, as well as for adjusting the makeup of the body composition of athletes (Rosenbloom et al., 2002). However, it is noteworthy that despite possessing this knowledge, many athletes struggle to translate it into appropriate dietary alternatives (Sakamaki et al., 2005; Debnath et al., 2019).

Only a minority of athletes consistently make satisfactory dietary choices when faced with a list of meals (Sakamaki et al., 2005). The majority lacks a comprehensive understanding of nutritional healthy practices and lack experience in making informed nutritional daily decisions (Hornstrom et al., 2011). Closing the knowledge gap in nutrition and practical dietary choices remains a challenge for many athletes.

Despite extensive research on nutrition knowledge, dietary habits, and information sources among athletes, there remains a notable gap in understanding these aspects among footballers and coaches, particularly at the professional level. Previous studies often centered on collegiate athletes, revealing deficiencies in nutritional knowledge that hinder adherence to recommended guidelines by authoritative sports medicine and dietetic associations. In 2000, the American Dietitians of Canada (ADC), American College of Sports Medicine (ACSM), and American Dental Association (ADA) released a joint statement outlining the significance of nutrition for athletic performance. They reported, Physical activity, athletic performance, and recovery from exercise are enhanced by optimal nutrition.

Studies conducted a decade apart by Torres-McGehee et al. (2012) and Rosenbloom et al. (2002) underscored persistent misconceptions among athletes regarding macronutrients, micronutrients, and supplementation. Such knowledge gaps raise concerns for performance and the athletes' overall health and well-being. While athletes receive guidance from various sources, including teammates, magazines, and parents, studies indicate that athletic trainers and coaches serve as primary resources for nutritional advice. However, the research has shown a lack of nutritional knowledge among coaches as a whole.

Optimal nutrient intake, nutritional knowledge, dietary habits, and nutritional practices influence athletes' performance, training quality, and post-exercise recovery (Beck et al., 2015). However, the researcher's experience highlights a prevailing belief among coaches, physical trainers, and players that attributes poor competitive performance and fitness levels primarily to training and talent, often overlooking the role of nutrition.

Football stands as one of the world's most renowned sports, captivating millions of viewers with its widespread appeal. The game's popularity continues to surge, drawing an ever-expanding audience on a daily basis (Islam & Rahman, 2021). This study in Ethiopia addresses a lack of information on nutritional knowledge, attitude, and dietary practices among U-17 football club players, coaches, and trainers. It aims to investigate potential correlations between poor performance and factors such as inadequate nutrition knowledge, unreliable information sources, and a lack of awareness about the impact of nutritional practices. Focusing on Ethiopian U-17 football club players, head and assistant coaches, and physical trainers, the research aims to provide valuable insights for future studies. The primary objective is to examine nutritional knowledge, dietary habits, beliefs, and practices within this specific athletic community, aiming to fill existing gaps in understanding the nutritional dynamics.

Materials and Methods

Participants

This research focused on individuals involved with the Ethiopian U-17 football club in the 2022/23 season, specifically U-17 players from youth Gimbi administrative town of selected football club. With a set sample size of 26, representing the entire club population, participants were strategically chosen based on their roles. The main goal was to gain comprehensive insights into the nutritional knowledge, dietary habits, beliefs, and practices of these specific participants within the club.

Study Design

The study used a descriptive survey research method, which randomly distributed a standardized questionnaire developed by Parmenter and Wardle (1999) among 26 U-17 football projects to assess participants' understanding, attitudes, and dietary behaviors related to nutrition. The primary data employed by the researcher was obtained directly from coaches and players, while secondary data was collected from various documents, books, journals, websites, and related research papers. Following the feedback received from the pilot study, corrections and revisions were implemented to eliminate any ambiguity in questionnaire items and ensure the questions' validity, reliability, and language coherence. Subsequently, the refined questionnaire was distributed to selected football clubs.

Procedures

The research procedures were carefully crafted for a comprehensive understanding of nutritional dynamics within the Ethiopian U-17 football club in the 2022/23 season. Using a single cross-sectional design, the study considered objectives, data sources, and logistical factors. A pilot study, involving 26 subjects and translation into Afan Oromo, refined the questionnaire, achieving high reliability (Cronbach Alpha values: 0.83 for attitudes, 0.79 for dietary practices, and 0.78 for nutritional knowledge). A preliminary investigation was carried out to ensure the clarity, appropriateness, and length of the questionnaires. Ambiguous words were removed after their accurate interpretation. Purposive sampling with a sample size of 26, representing the club population, strategically allocated participants based on roles. Ethical considerations were prioritized, ensuring informed consent, participant confidentiality, and overall

well-being. Transparent communication, cultural sensitivity, and disclosure of conflicts of interest were integral to the research's ethical framework. The procedures aimed to provide valuable insights into the nutritional knowledge, dietary habits, beliefs, and practices of specific participants within the club.

Statistical analysis

Quantitative analysis with SPSS version 26.0 included descriptive statistics and various tests exploring relationships and differences between variables. Descriptive statistics, t-tests, Pearson coefficients, and one-way ANOVA were used to examine the data, with a significance level of 0.05.

Results

Using both Kendall's taub and Spearman's rho coefficients, the analysis aimed to uncover connections among variables related to nutritional habits and information sources. When examining the relationship between the source of nutritional information and specific dietary practices, such as meal timing before training or competitions, the findings indicated minimal correlations. The correlation coefficients for these associations ranged from 0.004 to 0.083, and none reached statistical significance ($p > 0.05$). Moreover, when exploring correlations among the dietary practices themselves, weak associations were observed, with the highest correlation between the two practices being 0.265 ($p = 0.145$), which did not reach statistical significance (Table 1).

Spearman's rho coefficients supported these findings, demonstrating negligible correlations between the source of nutritional information and specific dietary practices. However, the finding recommends that the source of nutritional data does not strongly influence or align with particular dietary patterns among the respondents.

The analyzed correlations and regression relationships among variables based on participants' responses. Age showed a negative correlation with certain dietary habits and a positive correlation with others. Notably, eating habits during the off-season strongly correlated negatively with age. While the correlations approached high significance (Table 2).

The regression analysis suggested potential associations between age and specific predictors, although many were statistically significant. The results provide valuable insights into potential relationships between age, nutritional habits, and training practices among respondents, emphasizing the need for further research to understand nuanced factors influencing these connections.

An analysis of variance (ANOVA) was conducted to assess whether there were significant differences in supplement intake, specifically "Multimineral" and "Creatine," based on different sources of nutritional information. For "Multimineral" supplements, the results showed that the between-groups sum of squares was 1.024, with 6 degrees of freedom, resulting in a mean square of 0.171. The F-statistic was calculated as 0.609, yielding a significant p-value of 0.001. Similarly, for "Creatine" supplements, the between-groups sum of squares was 0.838, with 6 degrees of freedom, resulting in a mean square of 0.140. The F-statistic was calculated as 0.621, and the associated p-value was 0.004 (Table 3, 4).

The ANOVA analysis of educational background and age's impact on the source of nutritional information for

Table 1. The correlation between athletes' sources of nutritional information and their dietary habits

Statically Part	Variables	r	MBB	MBB	MBT	HBG	MBG
	SNI	r	1				
	MBB	r	.004	1			
Kendall's taub	MBT	r	.089	.218	1		
	HBG	r	.059	-.145	-.057	1	
	MBG	r	.083	.265	.158	.163	1
	SNI	r	1				
	MBB	r	.013	1			
Spearman's rho	MBT	r	.098	.230	1		
	HBG	r	.073	-.157	-.059	1	
	MBG	r	.091	.288	.165	.179	1

r= correlation' SNI: Source of Nutritional Information, MBB: take a meal/snack or breakfast 3-4 hours before training, MBT: skip any meal before training or competition, HBG: Home matches, meals can be eaten 3-4hrs before the game, MBG: In away matches, meals can be eaten 3-4hrs before the game

Table 2. Age vs. nutrition knowledge of the respondents

Coefficients								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	SNI	-0.203	0.141	-0.307	-1.436	0.167	-0.499	0.093
2	BTC	-0.620	0.497	-0.245	-1.247	0.228	-1.660	0.421
3	MBG	-0.122	0.149	-0.166	-0.819	0.423	-0.435	0.190
4	MMBG	0.236	0.139	0.360	1.691	0.107	-0.056	0.528
5	DS	0.201	0.157	0.257	1.283	0.215	-0.127	0.530

SNI: Take a meal/snack or breakfast 3-4 hours before training, BTC: skip any meal before training or competition, MBG: Home matches, meals can be eaten 3-4 hrs before the game, MMBG: In away matches, meals can be eaten 3-4 hrs before the game, DS: During the off-season, do you train outside of football training in your time? (i.e., gym, cycling, swimming)

Table 3. Age vs. nutrition Knowledge of the respondents

ANOVA[a]						
	Model	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.099	6	0.350	1.639	.000[b]
	Residual	4.055	19	0.213		

[a]Dependent Variable: source of nutritional information;
[b]Predictors: (Constant), educational background of respondent, age of respondent

Table 4. Source of nutrition information vs. nutrition intake

ANOVA						
Nutrition	Groups	Sum of	df	Mean	F	Sig.
Multimineral	Between Groups	1.024	6	0.171	0.609	0.001
	Within Groups	5.323	19	0.280		
Creatine	Between Groups	0.838	6	0.140	0.621	0.004
	Within Groups	4.277	19	0.225		

Ethiopian U-17 football players yielded a strongly significant result (p = 0.00)(Table 5).

The ANOVA results for the model examining the impact of the belief "Good nutrition practices by football players can help improve their sports performance" on the dependent variable "source of nutritional information" were statistically significant (p = 0.046)(Table 6).

The analysis of variance (ANOVA) investigated the relationship between nutritional practices and factors (gender, age, education, and information sources) among Ethiopian U-17 football players. Results for practices like eating at half-time, using creatine, and drinking water showed significant associations (p > 0.05).

The Paired Samples Test revealed a significant difference between participants' reported sources of nutritional information and their perceived percentage of total calorie intake, specifically in relation to carbohydrates. The statistical analysis of the paired sample t-test indicated a significant value of 0.007 among U-17 football club players (Table 8).

Table 5. Source of nutrition information and age, educational background of the respondents

ANOVA[a]						
	Model	Sum of Squares	df	Mean	F	Sig.
1	Regression	8.986	2	4.493	1.025	0.000
	Residual	100.860	23	4.385		

[a]Dependent Variable: source of nutritional information;
[b]Predictors: (Constant), educational background of respondent, age of respondent

Table 6. Nutritional practice vs. age, gender, educational qualification and source of nutritional information

ANOVA[a]						
	Model	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	14.901	1	14.901	3.767	0.046[b]
	Residual	94.945	24	3.956		

[a]Dependent Variable: source of nutritional information;
[b]Predictors: (Constant), educational background of respondent, age of respondent

Table 8. Source of nutritional information vs. percentage of the total calorie intake carbohydrate

Paired Samples Test							
Variables	Paired Differences				t	df	Sig.
	Mean	SD	95% CI				
			Lower	Upper			
Source of Nutritional Information	1.03	2.25	0.128	1.94	2.35	25	0.007

Table 7. Nutritional knowledge vs. Age, Gender, Educational qualification and Source of nutritional information

ANOVA						
Nutritional Knowledge	Groups	Sum of Squares	df	Mean Square	F	Sig.
Do you eat at half-time	Between Groups	1.796	1	1.796	3.808	0.035
	Within Groups	11.319	24	0.472		
Do you currently use creatine	Between Groups	0.181	1	0.181	0.521	0.003
	Within Groups	8.319	24	0.347		
Drink water or sports drinks: During training	Between Groups	0.565	1	0.565	1.254	0.001
	Within Groups	10.819	24	0.451		
Drink water or sports drinks: Pre-match	Between Groups	1.463	1	1.463	3.637	0.000
	Within Groups	9.653	24	0.402		
Drink water or sports drinks: Half time	Between Groups	0.052	1	0.052	0.229	0.002
	Within Groups	5.486	24	0.229		
Drink water or sports drinks: Post-match	Between Groups	0.004	1	0.004	0.020	0.004
	Within Groups	5.111	24	0.213		
Pre-match meals can be eaten 3-4hrs before	Between Groups	0.017	1	0.017	0.033	0.001
	Within Groups	12.444	24	0.519		

Table 9. Attitudes and beliefs of respondents regarding nutrition

		Test Statistics		
No.	**Variables**	**Chi-square**	**df**	**Sig.**
1	Source of nutritional information	24.077[a]	6	0.001
2	Healthy foods are enjoyable	0.000[b]	1	0.078
3	As long as exercise you can eat what you like	0.538[c]	2	0.764
4	Body weight is more important than body composition	14.385[d]	4	0.006
5	Football players can enhance their sports performance through good nutrition practices	10.692[c]	2	0.005
6	Adopting good nutrition practices can aid in injury prevention for football players	0.154[b]	1	0.695
7	Player seeking to boost peak power output and endurance fitness would benefit most from a creatine supplement	7.692[c]	2	0.021
8	Athletes pursuing weight loss goals are advised to take appetite suppressants like thermogenic tablets	18.923[e]	3	0.000

The chi-square test analysis revealed significant connections in certain areas. Firstly, participants' choices of sources for nutritional information were found to be significantly associated, indicated by a chi-square statistic of 24.077 with a p-value of 0.001. Additionally, beliefs about the relative significance of body composition and body weight showed a significant association (chi-square = 14.385, p = 0.006), highlighting varying opinions. Furthermore, the belief that good nutrition practices enhance sports performance exhibited a significant association (chi-square = 10.692, p = 0.005), emphasizing the interconnectedness of nutritional beliefs and sports-related outcomes. On the other hand, beliefs about the enjoyability of healthy foods, the permissibility of unrestricted eating with exercise, the preventive role of nutrition practices in injuries, and the benefits of creatine supplementation did not show significant associations. Notably, the belief in using appetite suppressants for weight loss demonstrated a significant association (chi-square = 18.923, p = 0.000) (Table 9).

Discussion

In the discussion of the findings from several key insights emerge, shedding light on the intricate interplay of factors influencing the nutritional practices, knowledge, and attitudes of Ethiopian U-17 football club players.

The predominant reliance on coaches as the primary source of nutritional information underscores the pivotal role these mentors play in shaping athletes' dietary habits. The limited influence of formal sources, such as books and dietitians, suggests a potential gap in accessing evidence-based nutritional guidance. The lack of significant correlations between information sources and specific dietary practices highlights the complexity of athletes' nutritional behaviors, indicating the need for tailored educational programs. According to Jonnalagadda et al. (2001), teachers and coaches play a crucial role in encouraging players on what to eat and encourage them to practice healthy eating habits. De Palma et al. (2009) also conducted a similar study and found out that 72% of athletes and football players perceived fasting and exercise as a way of controlling their body weight. This information was found to come from their coaches and they followed to the latter indicating the significance of coaches in their nutritional habits.

The negative correlations between age and certain dietary practices, such as pre-training meals/snacks and eating habits during the off-season, introduce an intriguing dimension. While not statistically significant, these trends suggest potential age-related variations in nutritional habits, warranting further exploration. The non-significant impact of educational background and age on the source of nutritional information aligns with the broader narrative those players, regardless of these demographic factors, share similar patterns in seeking nutritional guidance. According to Carlsohn et al. (2012), younger athletes had lower levels of nutrition knowledge and worse dietary practices than older athletes. They also found that younger athletes were more likely to be influenced by peers and media in their dietary choices. Another study conducted by Burns et al. (2004) found that there was no significant difference in the source of nutrition information between athletes with different levels of education. They also found that there was no significant difference in the source of nutrition information between athletes of different ages.

The significant differences in nutritional knowledge across various domains, including nutrient replacement, optimal training meal timing, and perceptions of protein content, highlight the diversity in players' understanding. Age-related disparities in knowledge underscore the importance of tailoring educational interventions to different age groups within the U-17 football club. According to Heydenreich et al. (2014) athletes had higher levels of nutrition knowledge in some domains, such as energy balance and macronutrients, than in other domains, such as hydration and supplement use. They also found that athletes were more likely to have misconceptions about nutrition in some domains than in others. This study also found that athletes had higher levels of nutrition knowledge about some topics, such as the importance of breakfast and the role of carbohydrates in fueling performance, than about other topics, such as the importance of micronutrients and the risks of supplement use.

The observed difference in participants' responses between reported sources of nutritional information and the perceived importance of carbohydrates in a footballer's diet emphasizes the potential influence of information sources on athletes' nutritional beliefs. This finding signals a need for interventions that not only address knowledge gaps but

also consider the impact of information sources on athletes' perceptions.

The significant associations uncovered between attitudes toward nutrition and demographic factors, such as the source of nutritional information, underscore the nuanced nature of players' perspectives. While some attitudes are linked to specific factors, others, including beliefs about the enjoy ability of healthy foods and the benefits of creatine supplementation, show no significant associations. This implies that certain attitudes may be shaped by a combination of factors beyond demographic considerations. A study conducted by Kelly et al. (2023) found that athletes who received coach-led nutrition education had more positive attitudes toward nutrition than athletes who did not receive nutrition education. They also found that athletes with higher levels of education had more positive attitudes toward nutrition than athletes with lower levels of education.

The discussion findings illuminate the intricate web of influences on nutritional practices, knowledge, and attitudes among Ethiopian U-17 football club players. The implications extend beyond a mere understanding of these factors, emphasizing the need for targeted, nuanced interventions that consider the diversity within the player demographic and the influential role of coaches in shaping athletes' nutritional behaviors. Future research should delve deeper into the age-related nuances and further explore the effectiveness of tailored educational programs in fostering healthier nutritional practices among this specific population. A further study conducted by Burns et al., (2004) found that athletes who received nutrition counseling from an athletic trainer had more positive attitudes toward nutrition and better dietary practices than athletes who did not receive nutrition counseling. They also found that athletes with higher levels of education had more positive attitudes toward nutrition than athletes with lower levels of education. According to Davar (2012), college-going women hockey players had a moderate level of nutrition knowledge and positive attitudes towards healthy eating. However, there were significant differences in nutrition knowledge and attitudes across various domains, such as nutrient replacement, optimal training meal timing, and perceptions of protein content. This suggests that players' understanding of nutrition is not comprehensive and that there is a need for more targeted nutrition education interventions.

Conclusions

The study illuminates the pivotal role of coaches in shaping the dietary habits of Ethiopian U-17 football club players, with limited impact from formal sources. Despite weak correlations between information sources and dietary practices, the intricate nature of athletes' nutritional behaviors underscores the necessity for personalized educational initiatives accommodating diverse preferences and sources. Varied nutritional knowledge among players emphasizes the need for age-specific interventions, while nuanced associations between attitudes and demographic factors necessitate targeted strategies. The findings underscore the importance of tailored educational programs and advocate for ongoing collaboration among sports organizations, nutritionists, and educational institutions to continually enhance U-17 players' nutritional practices, knowledge, and attitudes.

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Conflict of Interest

The authors declare no conflicts of interest.

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Аналіз рівня поінформованості футболістів віком до 17 років в Ефіопії щодо питань раціонального харчування, дієтичних практик, ставлення до цих аспектів та результативності

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 8 с., 9 табл., 22 джерела.

Історія питання. Адекватна обізнаність у питаннях харчування має вирішальне значення для формування правильних харчових звичок, особливо серед спортсменів, оскільки має значний вплив на показники спортивної результативності. Це вказує на наявність консенсусу в галузі навчання з раціонального спортивного харчування серед фахівців, які працюють зі спортсменами.

Мета дослідження. Метою дослідження було оцінити рівень обізнаності гравців футбольних клубів Ефіопії віком до 17 років щодо питань харчування, ставлення до цього аспекту та дієтичних практик.

Матеріали та методи. Було застосовано метод описового дослідження, а також проведено стандартизоване анкетування серед 26 футболістів за принципом рандомізації з метою оцінки знань, ставлення та дієтичних практик учасників щодо питань, пов'язаних з харчуванням. Дані були проаналізовані з використанням t-тесту, коефіцієнта Пірсона та однофакторного дисперсійного аналізу ($p < 0,05$). За результатами аналізу надійності значення коефіцієнта альфа Кронбаха склало 0,83 для шкал, що визначають оцінку ставлення до харчових звичок та обізнаність щодо харчування (0,79 та 0,78, відповідно).

Результати. Статистично значущих відмінностей (p > 0,5) у даних, пов'язаних зі звичками щодо споживання їжі, віком або розумінням важливості харчування, не спостерігалося. Відзначено значні відмінності в показниках освітнього рівня (p <0,05). Статева приналежність та джерело інформації не були визнані кореляторами нутриціологічних знань, натомість вік та освіта були такими чинниками.

Висновки. Таким чином, дослідження не показало значущих відмінностей (p > 0,05) в оцінках знань щодо питань харчування залежно від віку, освіти та джерела інформації. Однак було виявлено істотну різницю (p<0,05) між спортсменами та спортсменками. Статева приналежність корелювала з дієтичними звичками, тоді як вік, освіта та джерело інформації не мали такого зв'язку. Ключовим фактором є концепція подальшої перспективи заохочення спортивних організацій, нутриціологів та навчальних закладів до постійного вдосконалення та покращення рівня знань щодо харчування, ставлення до цього питання та практичних програм для гравців U-17. Важливо також забезпечити стабільну релевантність та ефективність у динамічному розвитку в галузі спорту та питаннях раціонального харчування.

Ключові слова: ставлення, дієтичні практики, футболісти, нутриціологічні знання.

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REVIEW ARTICLE

Physical Activity Training Methods to Improve the Physical Condition of Volleyball Players: A Systematic Review

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Abstract

Study purpose. The study was aimed to identify exercise techniques used to improve the physical condition of volleyball players through literature studies.

Materials and methods. A systematic review of these previous studies was conducted. We studied articles published between 2014 and 2023 that explained how to prepare volleyball players to have better physical condition. Scopus, Web of Science, Google Scholar, and PubMed were used for the electronic search. We collected all the articles that discussed how to improve physical performance through exercise.

Results. To improve the physical condition of volleyball players, 50 publications used exercise techniques, which were categorized based on the physical condition that was evaluated and repaired. The following techniques are some of the ones that can be used: Neuromuscular, unilateral and bilateral, ballistic, plyometric exercises, combined weight and plyometric, mixed training with optimal load, COD & plyometric complex, strength, combined strength, eccentric trainings, repetitive sprint, resistant/non-resistant sprint, resistance training, exercises with elastic band, core training, combined core training; small-sided games training, aerobic interval training, blood flow restriction, intermittent training, and anaerobic speed endurance.

Conclusions. Following a thorough analysis, a number of training regimens were found to be effective in enhancing volleyball players' physical attributes, including muscular strength, aerobic and anaerobic endurance, speed and acceleration, explosive power, flexibility, agility, and balance.

Keywords: systematic review, physical activity, physical condition, volleyball

Introduction

The amount of activity and physiological reactions that occur throughout a volleyball game represents the physical challenges that come with playing it. Related physiological reactions are related to the psychological state of the individual. This is in line with what Aziz stated that Individuals can overcome the problems they face appropriately and effectively, able to manage the stress experienced, which is characterized by commitment, challenges, and control (Aziz et al., 2023). To provide alternative solutions, intensive individual counselling is needed. Rababa said Client Encounter1. Counselling is the process of interaction between a counsellor and clients to assist individuals in understanding themselves, overcoming personal, social, emotional, or academic problems, and reaching maximum potential in various aspects of life (Rababa et al., 2022). Likewise, volleyball players need a qualified psychological state and physical condition. Subekti suggests. Physical condition is the degree of state of a person's body, be it in prime condition or not (Subekti et al., 2021). Therefore, volleyball players need to be in top physical condition to handle the physical demands of playing at a high level of competition. Training sessions are a component of efforts to meet physical demands and include a systematic plan to achieve long-term career goals or formal preparation to

compete. Sistiasih said Volleyball is one of the most popular sports in all directions, especially in Indonesia, volleyball is a new prima donna with quite a lot of enthusiasts (Sistiasih & Pradana, 2022). Volleyball matches or competitions have been running a lot.

The most important component of volleyball training is physical conditioning, which aims to maximize physiological capacity and advance bio motor abilities. Physical training can also be achieved in its style which is directed from a structural and developmental point of view towards the training objectives as volleyball has complex technical and tactical content. Only off-ball events are used to identify components of physical condition. A volleyball player is a functional unit that functions as a whole; As a result, their performance cannot be broken down into individual parts. This leads to the design of training programs that suit the demands of the sport. As a result, the purpose of the study was to test the training techniques used to improve the physical condition of volleyball players and to summarize the findings of each study. So that the process of physical conditioning exercises for volleyball games can be seen.

Physical training can also be done in its own style directed from a structural and developmental point of view towards the training goals because volleyball has complex technical and tactical content. Off-ball activities themselves are used to identify components of physical condition. The volleyball player is a functional unit that functions as a whole. As a result, their performance cannot be broken down into individual parts. This leads to the design of an exercise program that suits the demands of the sport. As a result, this study aims to investigate the training techniques used to improve the physical condition of volleyball players and explain the findings of each study, so that the process of physical conditioning exercises that go along with the game of volleyball can be observed.

Materials and methods

Database and Search Profile

Electronic searches on Google Scholar, Web of Science, Scopus, and PubMed were used to conduct this systematic review. "Training" and "Volleyball" are keyword combinations used for electronic searches. There are four phases to the search approach. First, 650 articles were found by electronic searches of the Google Scholar, Web of Science, Scopus, and PubMed databases. 450 articles were deleted in the second stage of filtering, which involved 200 article titles and abstracts. In addition, 85 items were omitted for various reasons, leaving 115 articles. In the third step, the full paper is reviewed and analyzed, starting with the title, abstract, methodology, results, and discussion, as well as conclusions. After carefully examining the articles, 65 were expelled for failing to meet the requirements for inclusion. The fourth step involves reading related papers. No new studies are included at this time. As a result, there were a total of 50 publications under systematic review (Figure 1). The inclusion and exclusion criteria are described in table 1.

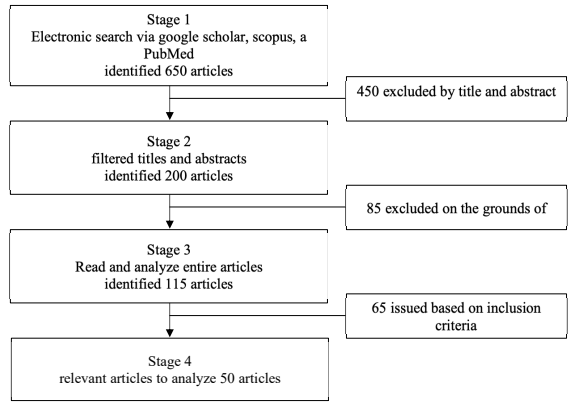

Fig. 1. Article identification flowchart in systematic review

This systematic review was done using electronic searches on Google Scholar, Web of Science, Scopus, and PubMed. Keyword combinations like "Volleyball" and "Training" are utilized in electronic searches. The search strategy is broken down into four steps. First, an electronic search of the Scopus, Web of Science, Google Scholar, and PubMed databases yielded 650 articles. The second round of screening, which included 200 article titles and abstracts, resulted in the removal of 450 articles. There are now 115 articles after an additional 85 things were excluded for various reasons. The third phase involves reviewing and analyzing the entire manuscript, beginning with the headings, abstract, methods, findings, discussion, and conclusion. 65 articles were excluded after a thorough assessment because they didn't adhere to the inclusion criteria. To complete the fourth phase, related papers must be read. Not currently listed are any new studies. Consequently, the systematic review has 50 papers (Figure 1). In addition, table 1 explains the inclusion and exclusion criteria.

Table 1. Inclusion and exclusion criteria of a systematic review of physical activity

Inclusion Criteria	Exclusive Criteria
Last ten years (from January 2014 to March 2023) articles published.	Articles using samples between the ages of 15 and 30.
Published in English.	Articles that utilize a group of volleyball players who have cerebral palsy/special needs.
There is no further research other than experiments.	Players from other sports, outside of volleyball, are also used as samples in the article.
Volleyball players between the ages of 15 and 30 made up the sample of men and women included in the study.	Training sessions are not described in the paper.
The instruction is fully explained.	
Comparative study is a research methodology, and it affects physical activity.	
Physical activity is used as a method of exercise.	
The study findings explain changes in the physical condition evaluated.	

Methodological quality assessment

The quality of the articles studied was evaluated using 11 PEDro (Physiotherapy Evidence Database) criteria and had been assessed for methodological quality. Quality articles are critical to assist users in overcoming barriers such as lack of time and critical thinking skills as well as making it easier to integrate high-quality clinical research into clinical practice. Clinical practice guidelines and systematic reviews are not evaluated. According to Moseley et al. (2020), articles with a score of eight to eleven were rated as having high methodological quality, those with a score of four to seven as medium, and those with a score of four or less were low (Moseley et al., 2020).

Results

Number of Results Reviewed

On an electronic search through Google Scholar, Web of Science, Scopus, and PubMed, 650 articles were identified and found no duplicate articles. Then 400 articles were filtered by title and abstract, leaving 200 articles to reread. The results left 115 articles reviewed in total. Of the 115 articles, 85 were omitted to 50 articles meeting the notability criteria based on the PEDro scale. This article is grouped by physical condition (table 2).

Exercise Significance Results

Of the 50 articles selected and reviewed, regardless of gender, age, level of professionalism, novice or elite players, or type of training conducted, overall, 50 selected articles revealed significant results on the physical condition of volleyball players.

Discussion

Plyometric training

Plyometric training is an exercise program that increases strength and speed (Anitha et al., 2018). Volleyball players need to do this exercise because they need to be able to react quickly and strongly when attacking and defending (Meszler & Váczi, 2019). Thus, plyometric training has been shown to increase explosive action (Vetrovsky et al., 2019). This can be explained by the fact that different types of exercises are performed, which may have an impact on the results of the exercises (Moran et al., 2019). As Fischetti points out, et.al. (Fischetti et al., 2018), which combined weight training and plyometric exercise in a three-group experiment, it produced different benefits when combined with other activities (Bouteraa et al., 2020). One group did only weight training, one group did weight training and plyometric exercises, and one group served as a control (Peitz et al., 2018). Results

Table 2. Characteristics and results of physical condition training methods for volleyball players

Author, Year	Physical Condition Variable	Training Type	Sig.(p)
Copic et al. (2014)	Body composition and muscle strength	Predictors of jumping performance	Sig.
Manshouri et al. (2014)	Flexibility of hamstrings and posterior trunk muscles	The special protocol consisted of two parts: pilates exercises and volleyball exercises.	Sig.
Zwierko et al. (2014)	Agility and passing skills	Extensive experience with volleyball training reduced signal conductivity time through visual pathway	Sig.
Bojanić et al. (2015)	Coordination, speed, explosive strength, repetitive strength and flexibility	Motor skills	Sig.
Papadopoulou (2015)	Balance, and performance	Energy intake and balance on the athletic performance	Sig.
Kalaja et al. (2015)	Speed and accuracy	Effect of caffeine	Sig.
Sattler et al. (2015)	Power and strength	Playing position and competition level	Sig.
Pereira et al. (2015)	Strength performance	Training strategy of explosive strength	Sig.
Stöggl et al. (2015)	Motor abilities and anthropometrics	Predictor motor ability	Sig.
Harmandeep et al. (2015)	Flexibility, muscular endurance, power, cardio-respiratory endurance	Six-week plyometrics on vertical jumping ability	Sig.
Çđmenlđ et al. (2016)	Flexibility, muscular endurance, power, cardio-respiratory endurance	Plyometric training on different surfaces	Sig.
Pion (2015)	Flexibility, muscular endurance, power, cardio-respiratory endurance	Selected plyometric training exercises	Sig.
Vaverka et al. (2016)	Power and strength	Arm swing on countermovement vertical jump	Sig.
Krističević, Tomislav, Madić, Dejan (2016)	Accuracy	Game-based conditioning training	Sig.
Ahmadvand et al. (2016)	Retention and transferring the progress	Mass & distributed practice	Sig.
Boichuk et al. (2018)	Coordination, speed, explosive strength, repetitive strength and flexibility	Physical development parameters and conditioning abilities	Sig.
Alishah et al. (2017)	Flexibility, muscular endurance, power, cardio-respiratory endurance	Attentional focus on the performance	Sig.

Table 2. Continued

Author, Year	Physical Condition Variable	Training Type	Sig.(p)
Faizrakhmanov et al. (2017)	Endurance	Effectiveness of the performance of certain game actions	Sig.
Brazo-Sayavera et al. (2017)	Speed, power, accuracy	Acute effects of block jumps	Sig.
Trajković et al. (2017)	Speed, power, accuracy	Weighted jump warm-up on vertical jump	Sig.
Gjinovci et al. (2017)	Flexibility, muscular endurance, power, cardio-respiratory endurance	Functional movement patterns	Sig.
Challoumas & Artemiou (2018)	Coordination, speed, explosive strength, repetitive strength and flexibility	Predictors of attack	Sig.
Czaplicki et al. (2017)	Strength and power	Biomechanical assessment	Sig.
Stojanovic et al. (2018)	Body composition	Short-term preseason combined training	Sig.
Hale et al. (2019)	Power, agility and strength	8-week conditioning program	Sig.
Arte, Yanse et al. (2020)	Power, agility and strength	Plyometric exercise and arm muscle strength	Sig.
Tsoukos et al. (2019)	Anthropometric and motor performance	Variables are decisive factors	Sig.
Vivekanth, B. Vallimurugan (2020)	Flexibility, muscular endurance, power, cardio-respiratory endurance	16-week combined strength and plyometric training program	Sig.
Trajković & Bogataj (2020)	Motor competence and physical performance	Neuromuscular training	Sig.
Ramirez-Campillo et al. (2020)	Strength and power	Plyometric jump training	Sig.
Freitas-Junior et al. (2020)	Power, agility and strength	Improvement in vertical jump	Sig.
García-de-Alcaraz et al. (2020)	Power and strength	Analysis of jump load during	Sig.
Wong & Leung (2020)	Physical fitness	Physical disabilities	Sig.
Andrade et al. (2021)	Performance, flexibility, muscular endurance, power, cardio-respiratory endurance	Training load and recovery	Sig.
Gonçalves et al. (2021)	Flexibility, muscular endurance, power, cardio-respiratory endurance	Neuromuscular jumping performance	Sig.
Ahmadi et al. (2021)	Strength performance	Plyometric jump training	Sig.
Nasrulloh et al. (2021)	Power	Squat training and leg length	Sig.
Lima et al. (2021)	Agility and passing skills	Reliability of a reactive agility test	Sig.
Albaladejo-Saura et al. (2022)	Physical fitness	Maturity status on kinanthropometric and physical fitness	Sig.
Nishanbayevich (2022)	Flexibility, muscular endurance, power, cardio-respiratory endurance	Developing physical qualities	Sig.
Issa (2022)	Anaerobic capacity, functional indicators	Interval training and drinking vital water	Sig.
Cieśluk, (2022)	Basic technical elements	Repeated short-term physical exercise	Sig.
Achilleopoulos et al. (2022)	Balance and technical skills	Proprioception and balance training program	Sig.
Tesfaye & Hundito (2022)	Performance	Physical fitness training	Sig.
Mamirzhon (2023)	Physical qualities	Development of the physical qualities	Sig.
Sulaymanov Qurbanali (2023)	Physical condition	Special physical training	Sig.
Kaszuba et al. (2023)	Physical performance	Caffeinated chewing gum	Sig.
Slovák et al. (2023)	Power, agility and strength	Predicting the volleyball spike jump height	Sig.
Rebelo et al. (2023)	Performance, flexibility, muscular endurance, power, cardio-respiratory endurance	Preseason triphasic resistance training program	Sig.

after six weeks of training showed that, when compared to weight training alone, plyometric exercises improved sprint, acceleration, and deceleration, as well as jumping, more effectively (Zghal et al., 2019). A gradual increase in plyometric exercise volume results in better results for improved muscle performance (Stojanović et al., 2017).

Strength training

Strength is the most important component and is the basis for other components of physical condition and is one of the components of physical condition that is needed in almost all sports (Gäbler et al., 2018). Therefore, improving the ability of the strength component is very important to get the attention of trainers. Strength is a component of physical condition that can be improved to the maximum extent, according to the needs of each sport that requires (Jamka et al., 2022). The strength needs of weight lifting, will be much different from those of sports games(Murlasits et al., 2017). Muscle strength can also be defined as the power or tension of muscles to perform repetitive or continuous work against resistance in a maximal effort (Jamka et al., 2021).

Endurance training

Endurance is one of the main elements in motor skills, which is the result of students' psychological capacity to support movement at a certain time (Fathir et al., 2021). Muscular endurance is the ability of muscles to maintain movement with high intensity or static exercise (Fathir et al., 2021). Endurance expresses a state that emphasizes the capacity to perform continuous work in an aerobic atmosphere. Endurance is the ability to perform activities for a long period of time without significant fatigue (Fathir et al., 2021). Endurance in terms of muscle work is the ability to work a muscle or group of muscles in a certain period of time, while from the energy system is the work ability of body organs in a certain period of time (Krzy et al., 2021).

Neuromuscular training

The majority of studies in adolescents look at neuromuscular training as a method that combines strength, balance, and agility (Eken & Bayer, 2021; López-Samanes et al., 2018). In prepubertal exercise (age 8 years) in the experimental group showed after 12 weeks considerable improvements in flexibility, balance, and countermovement of vertical jump height. The neuromuscular training program improves performance in vertical jump, one right foot jump, and one left foot jump (López-Samanes et al., 2018; Zemková & Hamar, 2018; Zeng et al., 2022). This showed that participating in a 6-week neuromuscular training program improved certain athletic performance metrics and modified movement patterns in female volleyball players during jumping tasks (Zemková & Hamar, 2018). After completing a 7-week neuromuscular training program, the experimental group showed an increase in hamstring strength, allowing them to maintain muscle performance (Concha-Cisternas et al., 2023a). Basically, a 6-week neuromuscular training program dramatically improves agility (Concha-Cisternas et al., 2023b).

Resistance training

Strong muscles are very important for volleyball players because they facilitate movements used in sports, such as running and jumping (Behm & Colado Sanchez, 2013; Faigenbaum et al., 2022). Protein in muscle cells is stimulated by resistance exercise, which increases the capacity of muscles to produce strength (Nóbrega & Libardi, 2016). Resistance training using a nonlinear periodization model significantly increases muscle strength and strength without compromising speed and agility (Borde et al., 2015; Mann et al., 2014). The main purpose of resistance training is to tear or cause microscopic damage to muscle cells, which the body then repairs quickly to recover and become stronger (Pallarés et al., 2021).

Circuit training

Circuit exercises should be chosen to change muscle groups, with better effort and faster recovery (Dhiman, 2022). Rest intervals between 60-90 seconds with 1-3 minutes between circuits. In line with the purpose of the stages concerned with preparation, and especially the purpose of anatomical adaptation, exercises should be chosen to develop the field of the bodies for the better as the prime mover (Sari et al., 2021). Bompa and Buzzichelli (2018) revealed that the advantages of training using Circuit are: a) improving various components of physical condition simultaneously in a relatively short time., b) each sportsman can train according to his own progress, c) each sport can correct his own progress, d) training is easy to supervise, e) saving time, because with a relatively short time it can accommodate many people practicing at once.

The circuit should not be used as a test or to make comparisons between sportsmen. Comparing sportsmen is unfair, because of the speed of performance. Instead, achievements need to be only compared to the abilities of previous sportsmen (Uchenwoke et al., 2020). The circuit can be used in the first week of anatomical adaptation. Start by testing the athlete for RM 1 to calculate the load for the main movements (J. Kim et al., 2018). Choose Circuit stations according to the needs of the sport being trained. A certain progress must be followed, depending on the level of the athlete and training background (Tsegay et al., 2021). For easier exercisers with little or no background in strength training, start with exercises using their own body weight (Tsegay et al., 2021).

Intermittent training

The capacity to repeat high-intensity exercise is very important because volleyball games are sporadic. To increase the physical demands with the actual requirements of the competition, intermittent exercise training can be carried out (García-Pinillos et al., 2017). A sportsman undergoes intermittent training for 12 weeks (2-3 sessions per week), consisting of sprints with 4-8 sets per session and a work period of 10 minutes. 30 seconds, with a recovery period of 10 to 30 seconds, shows important variation in aerobic performance (S. H. Kim et al., 2017). Therefore, because it reduces lactic acid buildup and injury hazards, intermittent training is a simple training strategy, especially for young athletes (Haller et al., 2018). The recovery phase, in which the heart rate is considered low if it lasts more than 30 seconds, is another important phase to watch out for, as the study suggests (Zemkov & Pacholek, 2023).

High-intensity interval training

According to (Chrøis et al., 2020) using HIT will increase endurance. Upregulation of aerobic and anaerobic

metabolism to energy requirements is a contributing factor in this increase. High-intensity interval training programs are used to increase cardiorespiratory capacity, according to some studies (Rabbani et al., 2019). On the other hand, the results of high-intensity interval training programs may also vary. A 12-week high-intensity interval training program can produce positive changes in muscle fitness, flexibility, and metabolic parameters in children (Taylor et al., 2021). The speed, acceleration, and agility of the experimental group improved significantly after completing an 8-week high-intensity interval training program (Fakhri et al., 2020). When paired with other forms of exercise, they also produce a wide range of maximum results (Byrd et al., 2019).

Functional training

Strength, endurance, coordination, and balance are just a few of the different measurements of muscle fitness that are thought to aid functional training (Babu et al., 2019). Functional training involves special physical exercises that build strength throughout the human body (Cheng et al., 2020). When performing exercises correctly during functional training, the mobility and stability of the athlete will increase. The likelihood of accidents occurring during the effort is reduced by this greater capability (Box et al., 2019). According to Deblauw et al. (Deblauw et al., 2021), functional training for 6 weeks with 4 sessions per week in the form of circuits improves agility test scores. The first two weeks involved three laps at each station, each lasting 20 seconds with a 90-second break in between. Weeks 3 and 4, three laps at each station, each lasting 30 seconds, with a 90-second break in between. Weeks 5 and 6, three laps at each station, each lasting 40 seconds, with a 90-second break in between.

Unilateral and Bilateral training

Unilateral and bilateral training tactics have arisen as a result of the explosive action of the modified neuromuscular system. Both of these exercises are equally effective in promoting strong growth and increased strength (Hung et al., 2019; Liao et al., 2022). These two exercises when combined can have a huge impact (Núñez et al., 2018). Training the 11-year-old volleyball player unilaterally and bilaterally and combining the two exercises, found that the results varied. 13 of the 21 performance indicators showed significantly greater changes after 6 weeks of training when unilateral and lateral training were combined, compared to 6 and 3 for unilateral and bilateral training, respectively (Eliassen et al., 2018; Jacksteit et al., 2021; Ramirez-Campillo et al., 2018). To significantly improve performance during high-intensity, short-term explosive activity, a combination of these two exercises would be more beneficial (Gonzalo-Skok et al., 2019; Sun et al., 2018).

Conclusions

After a thorough analysis, it was found that many training programs to improve the physical condition of volleyball players, including strength, aerobic and anaerobic endurance, muscle strength, speed and acceleration, flexibility, agility, explosive power, and balance.

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Conflict of interest

There are no conflicts of interest in this work, according to the researcher.

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Методи тренування фізичної активності для покращення фізичного стану волейболістів: систематичний огляд

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 12 с., 2 табл., 1 рис., 108 джерел.

Мета дослідження. Метою дослідження було визначити методики виконання фізичних вправ для покращення фізичного стану волейболістів на основі аналізу літературних джерел.

Матеріали та методи. Проведено систематичний огляд даних попередніх досліджень. Ми досліджували статті, опубліковані між 2014 і 2023 роками, в яких пояснювалися аспекти підготовки волейболістів з метою покращення показників фізичного стану. Для електронного пошуку використовувалися наукометричні бази даних Scopus, Web of Science, Google Scholar і PubMed. Ми зібрали всі статті, в яких було обговорено способи поліпшення рівня фізичної продуктивності за допомогою фізичних вправ.

Результати. Для покращення фізичного стану волейболістів у 50 публікаціях застосовувалися методики фізичних вправ, які було розподілено за категоріями залежно від показників фізичного стану, що оцінювались та корегувались. Нижче представлено деякі з таких методик, які можна застосовувати в цьому випадку: нервово-м'язові вправи, односторонні та двосторонні, балістичні, пліометричні, комбіновані вагові та пліометричні вправи, змішані тренування з оптимальним навантаженням, вправи зі швидкою зміною напрямку (ШЗН) та пліометричний комплекс, силові, комбіновані силові, ексцентричні тренування, повторний спринт, спринт з опором/без опору, тренування із опором, вправи з використанням еластичної стрічки, тренування для зміцнення м'язів кору (цілий комплекс м'язів, які відповідають за стабілізацію тазу, стегон і хребта, підтримку внутрішніх органів), комбіноване тренування м'язів кору; ігри з обмеженим простором, аеробне інтервальне тренування, обмеження кровотоку, інтервальні тренування та анаеробна швидкісна витривалість.

Висновки. Після ретельного аналізу було встановлено, що низка тренувальних програм виявилася ефективною щодо покращення фізичних якостей волейболістів, зокрема показників м'язової сили, аеробної та анаеробної витривалості, швидкості та прискорення, вибухової сили, гнучкості, спритності та рівноваги.

Ключові слова: систематичний огляд, фізична активність, фізичний стан, волейбол.

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REVIEW ARTICLE

Using a Biomechanical Analysis Approach to the Accuracy of Shooting Throws in Petanque Sport: Literature Review

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Abstract

Study Purpose. The purpose of this study was to determine how biomechanical analysis can be used in petanque shooting techniques.

Materials and methods. This review study followed the PRISMA standards for systematic reviews and meta-analyses. Studies had to be published within the previous five years, from January 2019 to July 2023. (1) shooting petanque; (2) biomechanical analysis were the keywords used in the search process. Scopus and the Science and Technology Index (SINTA) were used for study.

Results. This review consists of nine studies. In five research articles, motion analysis was considered, which resulted in a discussion of the direction and angle of petanque throw biomechanics. Four research articles deal with the analysis of petanque shooting accuracy, leading to a discussion of angle, direction, arc, and focus.

Conclusions. Biomechanical analysis helps to understand intensity, speed, and posture for better bidding, improved performance, and reduced risk of injury, while increasing speed and efficiency, preventing muscle imbalances, and achieving better technical positions in shooting petanque sports.

Keywords: biomechanical, accuracy, shooting, petanque.

Introduction

The character of Petanque sports tends to require accuracy, anyone who wants to play Petanque no matter what age, position, gender is allowed to play this sport (Yulingga Nanda Hanief, 2019). Based on the purpose of its main mechanics, petanque games are included in sports that have the aim of achieving maximum accuracy. This means that the throw made must be right on a specific target to get the winning point (Apriani et al., 2021). Various studies have explored different aspects of the sport of petanque. Development of a shooting training model for beginners, emphasizing the importance of throwing accuracy (Badaru, Hasmyati, et al., 2021). Assessing interest in petanque among visitors to specific courses, and finding a mix of low to very high interest (Sahruni et al., 2023). The results highlight the need for training and development in this sport, especially in terms of human resources (Yahya Andi Amry, 2021). The results of the evaluation evaluated the athletes' shooting ability, identifying a need for improvement in this area (Isdarianti et al., 2022). These studies collectively underscore the importance of training, development and skill enhancement in the sport of petanque.

A systematic literature review is a method used to analyze, synthesize, and summarize the existing literature on a particular topic (Dwidienawati et al., 2023). This method involves a rigorous and systematic approach to collecting and analyzing data from relevant sources (Moher et al., 2015). The purpose of a systematic literature review is to provide a clear and objective summary of the current state of knowledge on a particular topic, identify gaps in the literature and suggest areas for future research. This method is widely used in various fields including education healthcare, sports science, psychology, social science, and business and management (Amjad & Fernandes, 2023).

Various studies have explored the application of biomechanical technology in sport, highlighting its potential in injury prevention, technique improvement and performance optimization (Leckrone, 2021). Biomechanics is the study of human movement and the interaction between forces acting on the human body (Toma & Irawan, 2022). Research in this area has been conducted in several different contexts. Biomechanical analysis in relation to shooting throws in the sport of petanque. It explains how biomechanics affect ball flight and the importance of an accurate ball impact point for a correct shot (Ariwijaya et al., 2021). Various studies have explored the biomechanical aspects of shooting in various sports. Apply mathematical and physical methods to analyze shots, focusing on arm trajectory, shot direction, angle, effort, and velocity (Zhen et al., 2015). The results of another study highlighted the challenge of maintaining postural stability in precision sports such as shooting, proposing a measurement chain to evaluate this aspect (Words, 2000). These studies collectively underscore the importance of biomechanical factors in shooting performance.

Accuracy training One of the factors that can affect the accuracy of shooting in petanque sports so that it is inaccurate and imprecise includes a lack of arm muscle strength and a lack of analyzing biomechanics (Badaru, Kasmad, et al., 2021). The results of the study where accuracy is the ability of an athlete to direct the ball to the intended target or target with a good and perfect landing (Istikomah, 2023). Accuracy in the biomechanical analysis approach is closely related to the accuracy of the shooting point distance and shot power, because of one's ability to control free movements towards a target.

There have been many studies conducted in the past that have resulted in several developments in improving shooting accuracy in petanque sports, including a model of shooting skills training in petanque sports (Sutrisna et al., 2018), android-based petanque sport module (Wulandari & Wibowo, 2022), Learning Media Video Tutorial Basic Techniques of Petanque Throwing (Ayu et al., 2022)

The main purpose of analyzing the biomechanics of petanque pointing motion is to find out errors in movement and ball motion will create optimal movement, find out errors in performing techniques completely and accurately, and create athletes who have the opportunity to become champions especially in matches. Petanque games are included in sports that have the aim of achieving maximum balance and accuracy. This means that the throws made must be right on certain targets to get the winning points. The character of petanque sports tends to require accuracy, anyone who wants to play petanque no matter how old, position, gender is allowed to play this sport. In accordance with the main purpose of petanque sports into the sport to achieve maximum accuracy.

Materials and methods

The words "Biomechanical Analysis" and "Petanuqe Sports" were searched for in articles published from Sinta (Science and Technology Index) and Scopus Collections (Science Citation Index Expanded. Social Science Citation Index. Arts & Humanities Sams Citation Index) from 2019 to 2023. As shown in the flow chart (Figure 1), a total sample of 9 articles was obtained from a total of 137 articles by following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. (PRISMA) (Moher et al., 2015) during the identification, suitability screening, and inclusion phases.

The following variables were taken into account in the literature review (a) annual trend of articles published between 2019 and 2023 (b) distribution of first author's institution (c) number of authors (d) field of study (training, health, other education management or mixed) (e) type of study (experimental, descriptive correlational, longitudinal) and (1) average number of citations per article.

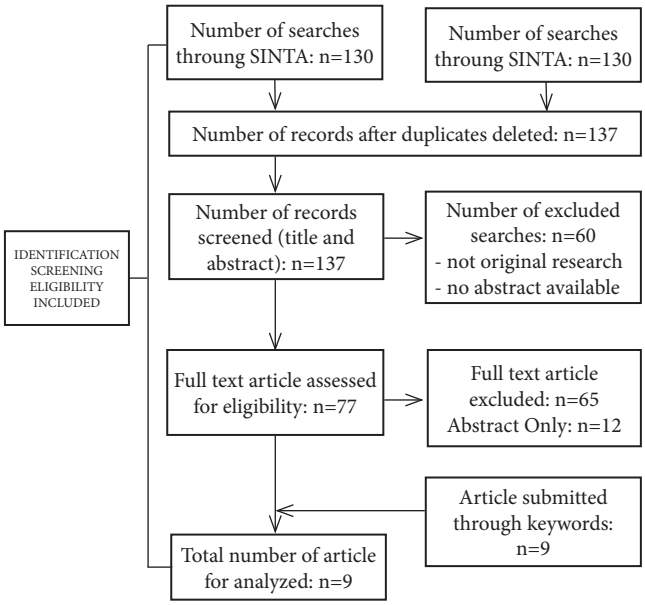

Fig. 1. Flowchart for what is used to select articles

The literature review considered the following variables: (a) the annual trend of articles published between 2019 and 2023; (b) the distribution of publications at the first author's institution; (c) the number of authors; (d) the field of study (health training education management, or mixed); (e) the type of study (experimental descriptive correlational, or mixed); and (f) the average number of citations per article.

Statistical Analysis

The abstract article title and keywords were focused on as these things are sufficient to generate reliable and usable article intı for follow-up research. Only open access articles were included in this review study as the authors did not want to exclude anyone who did not have access to their research. The following inclusion and exclusion criteria were used to obtain only relevant studies.

Result

Various time periods can be seen in the evolution of the number of publications, as depicted in Figure 2 First. there has been a marked increase in scientific output from 2019 (50 articles). Then in the following year there was a decrease in 2020 (10 articles) in the year there was an increase in 2021

Table 1. Changes in the number of publications per year

Year Published	Number of Articles	Percentage
2019	50	33%
2020	10	8 %
2021	22	16%
2022	30	25%
2023	25	18%
Total	137	100%

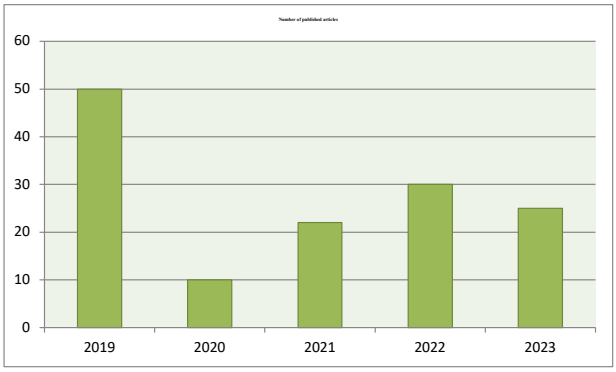

Fig. 2. Graph of Changes in the Number of Publications per Year

(22 articles) in the following year there was an increase in 2022 (30 articles) and in the following year 2023 (25 articles).

Based on the literature the biomechanical analysis that can be applied in the petanque shooting throw technique is shown in the table above. The review consists of nine studies. In five research articles, motion analysis is discussed, resulting in a discussion of the direction and angle of petanque throw biomechanics. Four research articles discuss the analysis of petanque shooting accuracy, which results in a discussion of angle, direction, arc, and focus. Based on throwing mechanics in petanque, the main goal is expected to produce accuracy in throwing and shooting. Biomechanical analysis is used to address the problems that occur in petanque shooting and provide recommendations on what is needed to improve performance.

Discussion

Based on the results of the study, there are four main indicators that determine shooting, namely backswing angle, swing, release angle, and ball height. The four indicators are interrelated and influence each other. the backswing angle will affect the swing speed, and the swing speed will affect the release angle of the ball, and these three indicators will produce the maximum height of the ball. In shooting there is no definite reference to the four indicators (Sinaga & Ibrahim, 2020). There are three indicators in determining the results of the shooting throw movement, namely the backswing angle, swing speed, and release angle, if the backswing angle, the release angle is small then the swing speed must be large in order to reach the target at a distance of 8 meters. Vice versa, if the backswing angle and release angle are large, the swing speed needed is also small in order to reach the target at a distance of 8 meters, this is in accordance with what was stated by (Cahyono et al., 2018). These three indicators affect the results of shooting throws, if one indicator is more dominant then other indicators are required to adjust because these three indicators are interrelated. Seeing the acquisition of shooting precision samples with an average score of 19.6 and included in the "medium" category, so it is necessary to increase shooting practice so that it can achieve maximum results.

Various studies have explored the factors that influence shot accuracy in petanque. That eye-hand coordination, concentration, and confidence play an important role in shot accuracy. Further demonstrating the effectiveness of shooting drills using obstacles in improving shooting game ability (Saifulamri Alkhusaini et al., 2021). Other research also argues that the development of a petanque shooting training model for beginners, by emphasizing the importance of training to achieve high throwing accuracy (Badaru, Hasmyati, et al., 2021). Then the results of another study comparing the effects of concentration and

Table 2. Study summary table

Topic	Sample	Results	Source
Biomechanical analysis of pointing and shooting petanque on athletes TC PON XX Papua	Athlete	Angle, Direction	Sinaga & Ibrahim (2020)
Biomechanical analysis of concentration and coordination on the accuracy in petanque shooting	Students	Angle, Direction, and Focus	Awang et al. (2019)
Analysis of Pointing Motion in Petanque Sport	Athlete	Angle, Direction	Bustomi et al. (2020)
Analysis of Backswing and the Use of Star Excursion Balance Test (SEBT) on the Results of Petanque Shooting Throws	Athlete	Angle, Direction	Awang Irawan & Sirodjul Munir (2021)
Analysis Of The Level Of Shooting Ability Of Petanque Athletes	Athlete	Angle, Direction	Ulpiana et al. (2022)
Analysis of Pointing Motion in Squatting Position from Biomechanical Aspects	Athlete	Angle, Direction	Paulina & Irawan (2022)
Analysis of pointing accuracy on petanque standing position: Performance and accuracy	Athlete	Angle, Direction, and Focus	Irawan et al. (2022)
Accuracy Training Program: Can Improve Shooting Results of Petanque Athletes	Athlete	Angle, Direction, and Focus	Phytanza et al. (2022)
Investigation into the mechanisms leading to explosion of pétanque balls	Athlete	Angle, Direction, Curvature, and Focus	Loser et al. (2011)

coordination training on shooting game ability, found that both were significant but concentration training gave better results (Lubis & Permadi, 2021). These studies collectively highlight the importance of physical and mental training in achieving shot accuracy in petanque. Utilizing biomechanics for training allows for smart practice planning so that you can get the most out of it in the shortest amount of time and in the safest way possible.

The study of sports biomechanics helps people understand how the body reacts to intensity, angles and postures in sports. In other words, studying sports biomechanics helps players choose the sport that suits them best. When poor form and technique are used, biomechanical analysis can highlight the details and help understand the stress that poor technique puts on joints and surrounding tissues. Biomechanical analysis can help athletes of all ages and abilities to improve performance or reduce pain. In summary, the biomechanical benefits of improving speed and strength are as follows. and help eliminate muscle imbalances, which means less wear and tear on ligaments and joints, and better training technique

Sports biomechanics is the study of the mechanical principles of human movement and how they apply to sports performance. Over the past fifty years, there has been considerable development in motion analysis systems and computer simulation modeling of sports movements, the relevance and importance of functional variability of sports techniques has also been recognized (Tai et al., 2023). Factors such as self-concept of subject ability, previous subject experience, and future career aspirations influence sports science students' elective biomechanics enrollment decisions. Sports biomechanics research often relies on ordinary least squares (OLS) regression, but statistical learning methods such as ordered regression models can be used to handle high-dimensional data sets and improve variable selection. These models have been used to reduce the number of variables and identify key predictors of performance in sports biomechanics research (Kipp & Warmenhoven, 2022).

Biomechanics is a field that combines engineering, physics (specifically mechanics), and knowledge of the workplace environment. General biomechanics is a branch of biomechanics that studies the basic laws governing the organic human body at rest and in motion. Biomechanics is a study that specializes in analyzing segments of human body motion, one of which is quantitative data on angles in degrees (Hughes et al., 2021). Studying the impact of these components has two main advantages. First of all, this research enables training that improves skills while reducing the risk of injury. In addition, it improves performance and physical fitness in terms of strength, cardiovascular and flexibility. Performing biomechanical analysis has many benefits as it provides a wealth of data for different types of human movement analysis. Especially, biomechanical analysis can improve athletes' performance (increase their performance) and reduce the risk of injury.

Conclusions

Based on the results of the use of biomechanical analysis in petanque shooting techniques based on literature and research. Six articles focused on motion analysis, examining biomechanical area and speed in petanque shooting. The remaining articles discuss shooting technique, focusing on speed, area, distance and focus. Biomechanical analysis helps understand the impact of intensity, speed, and posture in shooting and helps players get more accurate shots. Analysis of biomechanical techniques can help athletes improve performance and reduce the risk of injury. Benefits of biomechanical analysis include increased speed and strength, reduced muscle imbalances, and better stance technique.

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Conflict of Interest

The authors reported no potential conflicts of interest.

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Застосування методу біомеханічного аналізу для визначення точності кидків на вибивання у петанку: огляд літератури

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

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

Мета дослідження. Метою дослідження було визначити, як біомеханічний аналіз може бути застосований у техніках вибивання куль у петанку.

Матеріали і методи. Дане оглядове дослідження проводилося відповідно до стандартів PRISMA з метою здійснення систематичних оглядів і мета-аналізів. Дослідження мали бути опубліковані протягом попередніх п'яти років, з січня 2019 року по липень 2023 року. (1) вибивання куль у петанку; (2) біомеханічний аналіз використовувалися як ключові слова в процесі пошуку. Для проведення дослідження використовували наукометричні бази даних Scopus та Індекс науки і технологій (SINTA).

Результати. Представлений огляд складається з дев'яти досліджень. У п'яти наукових статтях було розглянуто аналіз руху, що спричинило обговорення напрямку і кута біомеханіки кидка у петанку. У чотирьох статтях проведено аналіз визначення точності вибивання куль у петанку, внаслідок чого були розглянуті питання кута, напрямку, дуги та фокусування.

Висновки. Біомеханічний аналіз допомагає зрозуміти інтенсивність, швидкість і позицію для покращення ведення гри, підвищення результативності та зменшення ризику травм, одночасно збільшуючи швидкість та ефективність, запобігаючи розвитку м'язового дисбалансу, а також досягаючи кращих технічних позицій у змаганнях з петанку при вибиванні куль.

Ключові слова: біомеханічний, точність, вибивання, петанк.

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REVIEW ARTICLE

Brain Neuromodulation Effects on Sport and Nutrition: A Narrative Review

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Abstract

Study purpose. At the end of the twentieth century, the development of highly reliable and painless non-invasive transcranial brain stimulation techniques and devices has aroused great scientific and clinical interest in numerous fields. In neuroscience, since the introduction of innovative and non-invasive devices such as the brain stimulator, the investigation of cortical processes and their neural basis has played a fundamental role.

Furthermore, neuroscientists are attracted to therapeutic applications for the treatment of food craving. This narrative review is aimed to explain the growing and constant interest of neuroscientific experimentation in the field of non-invasive transcranial stimulation.

Material and methods. After an introduction explaining the historical evolution of NIBS, we will try to provide an overview of the two stimulation techniques (TMS and tDCS); we will describe the different types of stimulation that can be performed using these techniques, the excitatory/inhibitory effects, and the various mechanisms of action at the level of brain activity.

Results. We will also provide some elucidations regarding the implications of the facilitative/inhibitory effects, and how these stimulation methods can be used to advance knowledge of the neurofunctional organization of the brain.

Conclusion. The results of the study showed the effect of brain neuromodulation on sports and nutrition.

Keywords: Non-Invasive Brain Stimulation (NIBS), Transcranial Magnetic Stimulation (TMS), Transcranial Direct Current Stimulation (tDCS), Cortical Excitability, food craving.

Introduction

The search for perfection in the fields of sports and nutrition is unrelenting (Forbes et al., 2022). Athletes and the teams that support them are constantly looking for new ways to improve their physical capabilities, streamline their training schedules, and sharpen their minds (Shaw et al., 2022). In the midst of this never-ending quest for top performance, the fascinating field of brain stimulation has become a potent weapon in the athlete's toolbox (Forbes et al., 2022). Brain stimulation techniques have shown the ability to revolutionize sports performance and nutrition practices, from honing cognitive skills to adjusting bodily responses. Brain stimulation refers to the use of various techniques and technologies to modulate or regulate the activity of the nervous system, particularly the brain. It involves the application of electrical, magnetic, chemical, or other forms of stimulation to specific neural pathways or regions to influence their function (Antal et al., 2022a). The brain stimulation has a wide range of applications in medicine, research, and even some emerging applications in non-medical contexts. Neuromodulation is being explored for a variety of emerging applications, including

enhancing athletic performance, improving sleep quality, treating addiction, and even as a potential therapy for neurodegenerative diseases (Van Ophoven, 2023). The use of brain neuromodulation in the context of sports and nutrition involves the use of neuromodulation techniques, like transcranial magnetic stimulation (TMS) and transcranial direct current stimulation (tDCS) to optimize brain function and enhance different aspects of athletic performance, including cognitive function, motivation, and even appetite regulation (Kesikburun, 2022). In fact, neuromodulation techniques have been explored to enhance cognitive functions such as attention, memory, and decision-making. Athletes can use these techniques to sharpen their mental acuity, which is critical for strategic planning and focus during training and competition. Moreover, considering that the brain plays a central role in regulating appetite and food intake, these techniques could be investigated for their ability to influence appetite control, potentially assisting athletes in managing their dietary choices and body weight for optimal performance. Furthermore, brain stimulation techniques have demonstrated effects on stress, cognitive improvement, motivation, mental toughness and appetite regulation, all fundamental aspects for both sport and nutrition (Barwood et al., 2016; Dumel et al., 2018; Edwards et al., 2017; Hazime et al., 2017; Lattari et al., 2018; Wang et al., 2022).

Different non-invasive brain stimulation (NIBS) techniques affect neuronal states through different means. However, the stimulation of the human brain implies, as an essential element, that these methods can induce a variation in the membrane potential of neurons. The membrane potential is an electrical voltage, measurable in a difference between the inside and the outside of the neuron (Amassian et al., 1990). This difference is given by an imbalance of positive and negative electric charged with ions. In resting conditions, the membrane potential of a neuron remains stable, thanks to a precise distribution of ions between its interior and exterior (Matsumoto et al., 2013). However, neurons are dynamic entities, capable of undergoing substantial transient variations of the membrane potential which are the basis of the transmission of information, in particular through the generation of signals which take the name of action potentials (Groppa et al., 2012). The different brain stimulation methods can modify the state of the neuron through electric currents and, consequently, favor the generation or otherwise of action potentials (Vidal-Dourado et al., 2014). TMS is mainly a neurostimulation method which involves the induction of a depolarization of the neuronal membranes and the initiation of action potentials in the stimulated area by means of an electromagnetic induction (Woods et al., 2016). The tES is neuromodulation technique that through low-intensity electrical stimulation, induces a variation in the state of the membrane potential, altering the ionic fluxes. This alteration can be a hyperpolarization or a depolarization of the neuron (Simonsmeier et al., 2018). The tES does not involve the direct induction of action potentials, but a variation of the response threshold of the stimulated neurons, with a consequent modulation of the response that the neuron will be able to provide.

Materials and methods

This narrative review tries to explain the brain neuromodulation effects on sport and nutrition. After an introduction explaining the historical evolution of NIBS, the present work tries to provide an overview of the two stimulation techniques (TMS and tDCS); describe the different types of stimulation that can be performed with these techniques, the excitatory/inhibitory effects and the various mechanisms of action at the level of brain activity. This work will also provide some elucidations regarding the implications of the facilitative/inhibitory effects, and how through these stimulation methods the knowledge of the neurofunctional organization of the brain can be broadened. Finally, it will explain the role of brain stimulation in physical exercise and nutrition. The bibliographic search was carried out on Pubmed using the following keywords: Non Invasive Brain Stimulation (NIBS), Transcranial Magnetic Stimulation (TMS), Transcranial Direct Current Stimulation (tDCS), Cortical Excitability, food craving, sport, nutrition.

Results

TMS

TMS is a non-invasive technique that allows to stimulate/inhibit or further modulate neural activity of cerebral cortex without solution of continuity. Its technical characteristics make it an important and promising tool for analyzing higher cognitive functions and the central motor pathway, making it possible to explore excitability, motor conduction and central motor conduction time. From the outset, the main source of interest in this technique has been the possibility of assessing the functionality of the corticospinal pathway in healthy subjects or subjects with neurological deficits in the motor sphere (Wagner et al., 2007). In this way, the propagation properties of the corticospinal fibers that control the target muscle can be examined in detail and the cortical representation of these muscles can be mapped, making TMS an effective technique for studying brain plasticity. Experiments show that an electric current flowing in a straight conductor generates a magnetic field around itself: it follows that a change in the magnetic field can in turn generate an induced current (Fregni & Pascual-Leone, 2007). As far as magnetic phenomena are concerned, we can consider a magnet made up of two indivisible poles. This means that there are no positive or negative magnetic charges, and the very concept of magnetic pole is fictitious: magnetic forces are a manifestation of the motion of electric charges. The properties of a magnet do not depend on the presence of "magnetic charges" inside it but on the fact that it is traversed by electric currents. There are profound links between electrical and magnetic phenomena: the study of the reactions between these is the object of electromagnetism. Let us now consider a solenoid, formed by a wire wound in a cylindrical helix and traversed by an electric current. It creates output lines which are called magnetic flux (Rossi et al., 2021a). Inside the solenoid, in the central region, the flux lines are parallel to the axis equidistant, and the magnetic field is uniform. Outside, however, the intensity is lower, the lines of flow are divergent, and the field is not uniform since the flow, going out, branches out by reducing its intensity with an index inversely proportional to the square of the distance. The magnetic flux is measured in weber (Wb) while induction, which expresses the distribution of the lines of force in space, is expressed in the head which corresponds to weber/metre^2.

In summary, an electric current can generate a magnetic field and at the same time a variation of the magnetic field can generate an induced current. By applying these observations to the neurophysiological field, it can be understood that a rapid variation of a magnetic field applied to an area of the human body a real induced current originates in its, and therefore it causes a stimulation. This observation is underpinning the development of magnetic stimulation. The magnetic impulse comes generated by the passage of current in the coil. This pulse induces a current in an electrically conductive area, such as the human body. If the current has sufficient amplitude and duration, it is possible to stimulate the neuromuscular tissues in the same way as more conventional electrical stimulation (George et al., 2002). The safety level is today guaranteed because the TMS device has a capacitor which loads and unloads (Rossi et al., 2021b). Using the charger circuit, the energy stored in the capacitor is discharged to one level pre-determined in the front control panel up to a maximum of 2.8 kV. When the stimulator receives a trigger signal as input, the energy stored in the capacitor is discharged into the stimulator coil (Zhang et al., 2022). In a few milliseconds the discharge switch can develop large currents. The switch is constructed in such a way to conduct the current in a precise direction and therefore the stimulator produces a monophasic current discharge with no reverse current. The possibility of reducing heat dispersion in the coil is linked to the monophasic discharge. The coil consists of a flat circular coil in which a variable current flow capable of produce a magnetic field (de Goede et al., 2018). Over the years, different application of TMS have been proposed and tested: single-pulse (spTMS), paired-pulse (ppTMS), repetitive (rTMS) and pattern stimulations such as theta bursts (Rossini et al., 2015). The first devices capable of delivering only a single impulse found wide use in the clinical field in the evaluation of specific neurophysiological parameters: for example, the inducible response in a peripheral muscle after having detected the primary motor cortex (M1), in order to evaluate the clinical status of the pathway which, from the cortex, carries the signal to the peripheral muscles, generating the motor evoked potential (MEP) (Moscatelli et al., 2017; Jameson, 2023). In the experimental investigations, single pulse stimulations immediately found wide use in the field of neuroscience, to evaluate the role of a brain area in a specific function of interest. The first technological developments in the field of TMS led to the development of protocols which envisaged the use of ppTMS. These protocols provided for a conditioned stimulus (CS) followed by a test stimulus (TS), allow us to evaluate how two areas are connected to each other, through the induction of cortical facilitation or inhibition phenomena. In particular, they evaluate how MEP amplitudes can be modified on the basis of the interstimulus interval between CS and TS or on the basis of the subject's status (Rossi et al., 2001; Veniero et al., 2012). In numerous protocols, the experiment involves the use of a range of intensities of the CS to induce inhibition or facilitation (starting from values below the threshold, up to values above the threshold). The intensity of the TS is usually set at 110-120% of the central motor threshold. When the two stimuli are administered in two different areas, these protocols provide important information on the degree of connection between the two areas (i.e. cortical connectivity). At the beginning of the 90s, devices capable of administering different stimuli (defined trains of stimuli) in rapid succession (rTMS) were introduced, which allowed the use of this method also in other research area. If applied as a single pulse, the induced current has sufficient amplitude to depolarize neurons (neurostimulation). If applied repeatedly at various frequencies and for a few minutes, rTMS modulates cortical excitability, decreasing or increasing it. The modulatory effect of rTMS lasts longer than the stimulation period, generally at least as long as half of the stimulation period. Much of the research investigating the effects of rTMS on cortical activity has focused on the effects of motor area stimulation, as the excitability of this brain region can be easily measured with MEPs (Moscatelli et al., 2020; Moscatelli et al., 2016). There is a large consensus in the literature that the application of low-frequency (LF) rTMS trains, below 1 Hz, induces mainly inhibitory effects, while high-frequency (HF) stimulations, above 5Hz and up to 25 Hz, induce facilitative effects (Moscatelli et al., 2023). TMS follows the rules of logical inference: if cortical area "A" is involved in cognitive process "X", and is not involved in process "Y", the alteration of the activity of area "A" will lead to an impaired performance in "X" and not in "Y" (Antal et al., 2022b). By deductive reasoning, area "A" plays a causal role in process "X" (Bortoletto et al., 2021). The functional impact of TMS essentially depends on its ability to transiently influence neuronal activity, modifying information processing, based on the state of the stimulated area. The TMS offers the advantage of indicating, along a time continuum, when a specific cognitive event occurs. In this case, the stimulation method is spTMS, because it exploits the high temporal resolution of the magnetic pulse, which is in the order of milliseconds (Lefaucheur et al., 2020). These methods are useful not only to limit the temporal activation field of a given brain area, but also to highlight the different role that the airways play in the different moments of sensory and cognitive processing (Jannati et al., 2023). However, rTMS protocols also offer the possibility of defining precise time windows. Initially, the stimulation can be applied over a large time interval (about 500 ms), just to see if it is possible to interact with the execution of the task by stimulating a given area (Lefaucheur et al., 2014). Once the involvement of this area has been established in a given time window, it is possible to reduce the stimulation time by increasingly narrowing the window (Perinelli et al., 2019). Therefore TMS, applied according to specific experimental paradigms which mainly aim at identifying the moment in which an area comes into play in a cognitive process, can identify circumscribed temporal windows of information processing. In this case, it should be noted that the effects induced by spTMS, but also by on-line rTMS, are generally short-lived, i.e., approximately a few hundred milliseconds. The case of the long-term neuromodulation effects of rTMS applied in protocols defined off-line, i.e., before the execution of the task, or those resulting from the repeated application of rTMS is different. In the online application, the longer the stimulation period and the higher the rTMS frequency, the greater the interference on the activity of the stimulated brain region and the final effects, observable in the subject's behaviors (Savino et al., 2023). However, there is an increased risk of inducing non-specific behavioral effects, which can make the results more difficult to interpret. In these cases, the use of a TMS called sham, or ineffective/

placebo stimulation, is used. During sham stimulation a TMS is simulated, but no magnetic field reaches the underlying cortex. The simplest way is to interpose a non-conductive material 3 cm thick between the coil and the scalp, alternatively you can rotate the coil by 180° (Rossi et al., 2021b). As there are multiple brain regions that may be involved in exercise regulation, the rationale for using brain stimulation for performance enhancement and the regulation of food intake, may vary accordingly, which may provide an explanation for the inconsistent results of different studies (Machado et al., 2019). It seemed that different stimulation conditions and parameters may contribute to different results (Bastani & Jaberzadeh, 2012). Moreover, warm up or training exercises conducted simultaneously with NIBS have been adopted in a few previous studies, which may be a factor to influence the results (Park et al., 2019).

rTMS

The rTMS is defined as the application of a train of pulses of the same intensity to a single brain area at a given frequency and intensity. In general, high frequency stimulation, is correlated to interference with cortical functions during the application of the pulse train. However, following these immediate effects, a train of rTMS pulses can also induce sustained modulation of cortical excitability which can persist well beyond the duration of the train itself (Amanda S Morrison, Andero Uusberg, 2022). The modulation effect can range from inhibition to facilitation based on the stimulation parameters used, as was the case for ppTMS. Lower frequencies, for example 1 Hz, applied to the motor cortex can repress its excitability, while stimulation trains at higher frequencies, around 20 Hz, they lead to an increase of cortical excitability. These effects vary depending on of the individual considered and the shape of the trains, however in general the low frequencies (around 1 Hz) produce very long-lasting and robust effects and can therefore be applied to the motor cortex and other cortical regions to study the behavioral relationships of the brain (Gornerova et al., 2023). To obtain an even more persistent and important effect in the neuromodulation of the chosen area, various stimulation frequencies are usually combined. It should be emphasized for regarding the limits mentioned above, that they are not entirely arbitrary. It is in fact known, for example, that low frequencies around 1Hz can be correlated to depression or long-term potentiation following tetanic nerve stimulation: there is evidence that demonstrates that rTMS at high and low frequencies identified above produce relatively distinct both on direct measures of brain activity and behavior. Using rTMS therefore, frequency appears to be the key parameter determining the direction of effects, although other variables should be taken into consideration while planning an experiment with this method. For example, attention should be paid to the pulse train duration, the interval between two trains, the total number of trains and pulses in a session duration or over a given area. By respecting the parameters, two main ways of performing rTMS are defined: online and offline.

Transcranial Direct Current Stimulation (tDCS)

Transcranial Direct Current Stimulation (tDCS) is a non-invasive brain stimulation method able to induce functional changes in the cerebral cortex. The tDCS essentially consists in the application on the scalp of electrodes delivering a direct current of low intensity able to crossing the scalp and influencing neuronal functions, finding application in numerous clinical, diagnostic and research fields (Cabral et al., 2015; Lattari et al., 2016, 2020). If the study of the brain has always aroused great fascination in scientists since ancient times, the effects of the current on it have been objects of large scientific and non-scientific interest since its discovery in the world. In fact, the effects of uncontrolled brain stimulation have been reported since the past. Looking at the most recent history, the use of the therapy electroconvulsive and psychiatric drugs and the lack of reliable neurophysiological signals, obscured the use of direct current on the central nervous system as a therapeutic and research tool, especially in the field of psychiatry. However, galvanic current continued to be used without interruption in the treatment of musculoskeletal disorders and peripheral pain in the meantime. These first efforts in the neurophysiological field, therefore, were probably abandoned due to lack of reliable evaluation methods. When in 1998 it was possible to measure the effects of direct current application on the motor cortex non-invasively by means of transcranial magnetic stimulation, tDCS became reliable in terms of parameters such as stimulation intensity, duration and validation of its following plastic effects (Al-Tawarah et al., 2022).

From a technological point of view, the tDCS instrumentation has a rather simple structure compared to other stimulation devices. In fact, it is mainly composed of two electrodes and a battery device capable of supplying a constant flow of current in a continuous manner. These basic components can be connected to other components, such as for example a software that offers the opportunity to choosing between different stimulation protocol or multiple-session experiments. Naturally, since they must create a closed circuit once in operation, the two electrodes correspond to a cathode and an anode. By placing them over the scalp, it can be modulating a specific area of the central nervous system. The positioning of the electrodes therefore assumes a crucial role and is usually determined in line with the international system of EEG 10-20. For example, studies exploring the motor cortex place electrodes above zone C3 and C4. The electrodes used are usually sponge and the surfaces range from 25 to 35 square, but they can change in order of size. To create the homogeneous electric field responsible for the plastic effects of the neural tissue, and therefore necessary for tissue analysis, a direct current is usually made to flow inside the electrodes which can vary from 0.5 to 2 mA, for about 20-40 minutes. It can induce even lasting changes in the brain, both excitatory and inhibitory, while remaining subthreshold. This neuromodulation technique consequently provides a practical and less invasive alternative to, for example, direct stimulation. In fact, tDCS can be used in general to manipulate brain excitability by means of polarization membrane: a cathodal stimulation hyperpolarizes, an anodal stimulation depolarizes the resting membrane potential. In this regard, it should be specified that the current flow in question is a flow of ions present in the brain tissue. Therefore, the positive ions will tend to flow towards the cathode, while the negative ones will flow towards the anode. The flow comes conventionally considered directed from the

anode towards the cathode, creating as mentioned a closed circuit in which the current passes through the head. There are two main types of assembly for electrodes, but different nomenclature to define them. Therefore, for the sake of clarity, it is now necessary to discuss some terms used to describe the assembly of tDCS. When an electrode is placed under the neck, the entire assembly is referred to as "unipolar". Conversely, montages with the two electrodes on the head are usually referred to as "bipolar". This nomenclature, however, could be considered technically inaccurate, since DC stimulation is always generated by means of two poles (electrodes) which generate an electric dipole between the two electrodes. Therefore, an alternative nomenclature to use could be that of "monoencephalic" and "biencephalic" to differentiate the "unipolar" and "bipolar" set ups respectively. Researchers in the field also use the terms "reference" and "stimulation" electrode to refer to the electrode respectively neutral and active with respect to the area to be investigated. However, even the term "reference" can be problematic especially for the biencephalic montage because the reference electrode is not physiologically inert and can contribute to the modulation of activity as the active one (Woods et al., 2016). This could be a potential confounding factor. Nevertheless, the researchers use this term to underline that, in their studies, they assume that in their assembly one electrode will be considered for stimulation, while the other as reference.

Sport and brain stimulation

The brain stimulation is thought to have ergogenic potential for increasing muscular strength and stamina in both athletes and non-athletes (Goodall et al., 2014; Lattari et al., 2020; Moscatelli et al., 2023). The left dorsolateral prefrontal cortex (DLPFC) is the region that is most frequently targeted in studies of NIBS and sport because it controls the inhibition of motor regions. In general, this region plays a part in the modulation of many different processes and functions, including emotion, mood, and memory. Consequently, it is challenging to gauge the effect of a specific stimulus on just one metric (Karlinsky et al., 2017). One of the most crucial areas in determining whether or not to continue exercising is the left DLPFC since it controls exertion and weariness (Monda, Salerno, et al., 2017a). Physical exhaustion is a complicated process that may be influenced by elements like cerebral inhibition and perceived effort. EEG measurements of brain activity (beta power) during exhaustion show an increase along with a stronger synchronization between the left and right DLPFC (Antal et al., 2022a). When central tiredness brought on by exercise occurs and motor cortical activation declines, fatigue may be compensated in the DLPFC. Accordingly, Lattari et al. (2020) discovered that anodal tDCS applied to the left DLPFC and cathode over the Fp2 at 2 mA for 20 min improved volume load and perceived exertion in comparison to sham tDCS and tDCS employing a reversed montage for lower limb activity in healthy young people (Maldonato et. al., 2018). In comparison to sham stimulation, 20 minutes of anodal tDCS at 2 mA delivered over the left DLPFC (cathode over the Fp2) enhanced the tolerance to the maximal load exercise conducted in the cycloergometer in moderately active women. This study suggests that by preserving the volitional impulse to the motor cortex, altering the neuronal activity in the left DLPFC may improve endurance exercise performance. However, other investigations have not been able to demonstrate any discernible effects of tDCS on exercise performance (Barwood et al., 2016; Monda, Salerno, et al., 2017b; Polito et al., 2020). Recent studies on the improvement of jump performance have confirmed earlier studies on the facilitation of motor learning (Antal et al., 2022b). The possibility of enhancing gross motor power or endurance may be higher compared to the demands of skilled sports, if evidence on experienced musicians could be generalized to sports (Messina et al., 2015; Huang et al., 2009; Polito et al., 2019). An important review, 60% of the studies reported improvement in physical performance when a-tDCS was administered (Angius et al., 2018). More specifically to the type of exercise performed, 62% of the studies involving whole-body exercise reported an improvement in physical, with similar benefits for single-joint exercise (60%). Additionally, 60% studies investigating endurance (both in whole body and single joint exercise) found improvement in performance, while 57% of the studies have found improvement in strength, power, or anaerobic work capacity. However, the effects of tDCS on physical performances are highly variable. Authors suggested that the high inter-individual variability (i.e., responders vs non-responders) to NIBS and more specifically to tDCS could explain the variance in experimental outcomes (López-Alonso et al., 2015). In addition, the different electrode montages used and stimulation protocols could have surely contributed to mixed result. Likewise, due to differences in electrode size and position, as well as to the relatively low focality of induced electric field (Miranda et al., 2013), other brain areas beyond the targeted one could be affected by tDCS and profoundly affect the experimental outcomes. Overall, tDCS seems to improve endurance, strength, power and anaerobic capacity. Taken together, the currently available literature provides interesting insights about the potential for tDCS to enhance physical performance.

NIBS and eating behavior

The first study on non-invasive neuromodulation's use for controlling eating behavior was conducted in 2005 (Uher et al., 2005). The only methods that have been applied in this situation are TMS and tDCS. The targeted region of the brain is the complex DLPFC, which facilitates cognitive control of food intake and is associated with executive processes. The fundamental assumption is that increasing DLPFC activity may change the reward-cognition balance in a way that facilitates cognitive control and may even decrease reward-related systems that cause overeating and food cravings. It is still completely unknown which specific DLPFC -dependent cognitive functions are impacted by rTMS or tDCS and how this influences the reported behavioral effects. Changes in reward valuation mechanisms, attentional biases, or inhibitory control are a few possibilities (Messina et al., 2018; Moscatelli, Sessa, et al., 2021; Valenzano et al., 2019; Val-Laillet et al., 2015; Viggiano et al., 2010). Only the left DLPFC has been the subject of rTMS investigations using excitatory protocols (10 and 20 Hz). Both the right and left DLPFC have been the target of tDCS investigations, however with slightly different approaches/montages. The majority

of research have examined the effects on food seeking, perceived hunger, and food intake (all with tDCS, one with rTMS). Overall, they have consistently discovered a severe suppression of appetite and self-reported food cravings on ratings or visual analogue scales (VAS). There is some evidence that the tDCS impact may be more focused on sugar cravings (Esposito et al., 2016; Minervini et al., 2023; Monda, Nigro, et al., 2017).

The findings of these preliminary investigations offer a strong proof of concept for the application of non-invasive neuromodulation to the study of eating behavior (Messina et al., 2018). Potential applications include rebalancing ventral and dorsal brain systems or improving cognitive control and underlying brain regions to support successful weight loss maintenance in obesity (Bonnì et al., 2023; Moscatelli, Messina, et al., 2021; Sperandeo et al., 2018; Val-Laillet et al., 2015; Yao et al., 2023). The general justification for employing noninvasive neuromodulation in the treatment of obesity and eating disorders is pretty evident, but the specifics are still being researched, and the optimum methods and protocols have not yet been established. To produce synergistic results, noninvasive neuromodulation can be utilized alone or in combination with other approaches like behavioral treatment, cognitive training, physical fitness, and diet.

Over the past decade, there is an increasing interest to use brain stimulation as a novel treatment approach for obesity and eating disorders (Ester & Kullmann, 2022). It is evident that multisession studies are more effective to reduce food craving and consumption than single-session approaches (Chen et al., 2020; Song et al., 2019). Moreover, results from various studies suggest that brain stimulation has a positive impact on food craving, particularly for specific foods such as sweets. Most trials were conducted with very limited sample size, which makes it difficult to draw firm conclusions. Yet overall, the literature on tDCS effects on food intake and craving display a mix of positive and null findings. In addition, the exact mechanisms behind tDCS effects remain unclear. Further research should focus on a combination of neuroimaging techniques such as fMRI and tDCS in order to provide underlying mechanisms of anodal and cathodal stimulation. The fast growing literature in brain research elucidated that brain regions do not operate in isolation but interact constantly with each other (Siegel et al., 2015). Multifocal tDCS targeting a whole network increases excitability in the targeted brain area more than twofold over time compared to conventional tDCS (Fischer et al., 2017). Therefore, multifocal tDCS arrangements with smaller electrodes could facilitate to stimulate whole brain networks and thus not only target the DLPFC but indirectly stimulate other brain structures involved in eating behavior regulation (Cotoia et al., 2018).

Discussion

The integration of brain neuromodulation techniques into the realms of sports and nutrition represents a fascinating intersection of science, performance optimization, and human potential. This narrative review explores the multifaceted impact of neuromodulation on athletes' physical abilities, cognitive functions, and nutritional behaviors. One of the most prominent applications of brain neuromodulation in sports is its potential to enhance cognitive functions critical for peak performance (Moscatelli et al., 2023). Techniques such as transcranial direct current stimulation (tDCS) and transcranial magnetic stimulation (TMS) have shown promise in improving attention, decision-making, and memory. These cognitive enhancements can be particularly beneficial for athletes engaged in sports demanding split-second reactions, strategic planning, and complex problem-solving. However, it is essential to note the variability in individual responses and the need for personalized protocols. Athletes seeking cognitive enhancements should approach neuromodulation cautiously, under professional guidance, and with careful consideration of ethical concerns surrounding performance enhancement. Beyond sports performance, neuromodulation also extends its reach into the domain of nutrition. The ability to influence appetite regulation through brain stimulation may aid athletes in managing dietary choices, body weight, and overall nutritional strategies (Ciliberti et al., 2018; Monda et al., 2017). This can have profound implications for athletes who need to balance their energy intake and expenditure for optimal performance. However, the complexities of appetite regulation and the individual variability in responses underscore the need for continued research. Ethical considerations also loom large, especially regarding the potential misuse of neuromodulation for unhealthy dietary practices or body image concerns. The application of brain neuromodulation in sports and nutrition is a dynamic field, marked by promising possibilities and ethical dilemmas. As this technology evolves, regulatory bodies, sports organizations, and practitioners must collaborate to establish guidelines that balance performance enhancement with athlete safety and fairness. Research efforts should continue to elucidate the mechanisms, risks, and benefits associated with neuromodulation techniques in the sporting context.

Conclusion

In these approximately thirty years since the introduction of NIBS techniques, researchers have encountered various technical and theoretical difficulties in defining their optimal use and characterizing the mechanisms induced at a neural level. However, by virtue of the important discoveries and developments that have taken place in recent years, it would seem that the main technical difficulties have been resolved, the methodological bases seem to have been laid and also the operating mechanisms are starting to be clearer. On these bases, interesting scenarios for NIBS begin to be outlined in the clinical, rehabilitation, sport and nutrition fields, with numerous standardized protocols. Surely there is still a long way to go before we arrive at a complete sharing of theoretical models and standardized applications; however, the knowledge attained to date will provide an important background to inspire major advances in this scientific area.

Conflict of interest

The authors have any conflicts of interest to declare.

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Вплив нейромодуляції головного мозку на заняття спортом та харчування: описовий огляд

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Реферат. Стаття: 12 с., 83 джерела.

Мета дослідження. Наприкінці XX століття розробка високонадійних і безболісних неінвазивних методів і пристроїв транскраніальної стимуляції головного мозку викликала значний науковий та клінічний інтерес у багатьох галузях. У нейрології, з моменту впровадження інноваційних та неінвазивних пристроїв, таких як стимулятор мозку, дослідження кортикальних процесів та їх нейронної основи відіграє фундаментальну роль.

Крім того, увагу нейрологів привертає застосування терапевтичних методів для лікування потягу до їжі. Цей описовий огляд має на меті пояснити зростаючий і постійний інтерес до проведення нейрологічних експериментів у сфері неінвазивної транскраніальної стимуляції.

Матеріал та методи. Після вступної частини, що пояснює історичну еволюцію неінвазивної стимуляції головного мозку (NIBS); ми спробуємо надати огляд двох методів стимуляції — транскраніальна магнітна стимуляція та транскраніальна стимуляція постійним струмом (TMS і tDCS); ми опишемо різні типи стимуляції, які можуть бути виконані із застосуванням цих методів, ефекти збудження/пригнічення, а також різні механізми дії на рівні активності головного мозку.

Результати. Ми також надамо деякі пояснення щодо наслідків фасилітативного/інгібіторного ефектів і того, як ці методи стимуляції можуть бути використані для поглиблення знань з нейрофункціональної організації головного мозку.

Висновки. Результати дослідження показали вплив нейромодуляції головного мозку на заняття спортом та харчування.

Ключові слова: неінвазивна стимуляція головного мозку (NIBS), транскраніальна магнітна стимуляція (TMS), транскраніальна стимуляція постійним струмом (tDCS), кортикальне збудження, потяг до їжі.

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REVIEW ARTICLE

School Strategies on Improving Students' Physical Activity Engagement During COVID-19 Pandemic Period: A Thematic Review

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Abstract

Study purpose. Physical inactivity among school students was an existing health issue over the past decade. This became more alarming when the world was hit by the COVID-19 pandemic. Movement restriction that results temporary school closure significantly affect students' physical activity participation. Therefore, strategies and practices to improve active play engagement as well as to counteract its negative health-related effects on students were widely implemented by teachers and administrators in school upon its re-opening. Numerous articles have been published on the effectiveness of school-based interventions during the COVID-19 pandemic, but there is still a lack of a review paper that deals with the identification of patterns and trends about school practices in this area. Hence, this paper intends to generate impressions and identify concepts within the published articles during 2021 to 2023.

Materials and methods. Selected articles for this study were collected from the following databases: SCOPUS, Sage, ProQuest, Academic Search complete, Science Direct. Computer-assisted qualitative data analysis (ATLAS ti. 23) guided the comprehensiveness of this review. Study findings were generated and presented through quantitative and qualitative lenses.

Results. Four central themes were identified: 1) Alternative Physical Education – modifying traditional physical education subject; 2) Physical literacy focus – approach anchored to multi-dimensional foundation in physical activity engagement 3) Web-based intervention – virtual and cyberspace approach and 4) Needs-based intervention – focusing on integration of participants' attributes and specifically designed program.

Conclusions. The structure of strategies conducted by schools were greatly affected by the current community health status. Findings of this study will serve as a reference for designing future intervention approach to address the sedentary lifestyles of young populations associated to specific community health and other related issues.

Keywords: school, intervention, physical activity, ATLAS ti. 23, COVID-19.

Introduction

Sedentary lifestyle is a global issue within the past decade and still an upsetting issue at present. Sedentary behavior incidence was considerably on alarming stage globally (Carl et al., 2023). Health organizations and professionals are currently working on strategies and intervention to improve individuals lifestyle. World Health Organization (2022) keeps on disseminating information about movement guideline recommendation to help the globe overthrow inactivity. However, the campaign to fight sedentary behavior among society was tested by another challenge. This was when the world was hit by COVID-19 – pandemic few years ago.

COVID-19 brings huge change on community lifestyle all over the world (Marenus et al., 2023). Changes comes from societal daily routine to individual activity engagement preference. Among affected by the pandemic was the children, as they are confined to the house due to movement restriction policy. Physical activity as part of kid's daily life became one of the researchers interests during COVID-19 times. Being active through movement was very important to students positive growth (Wiklund et al., 2023). This was

supported by Gilic et al., (2023) cited that being active was positively associated to being healthy. According to Swierad et al., (2021) children became substantially inactive because of the virus spread.

COVID-19 – pandemic resulted temporary closure of schools as compliance to movement restrictions. According to Marenus et al. (2023) COVID-19 provides negative impact on students as they become more inactive and over engaged to gadget. This also contributes to students' inactivity as they missed the opportunities to be engage in physical activities usually done in school. According to Gallotta et al. (2022), chance of being active are high when in school as they can do some active games and plays. Therefore, school is a considerable venue to help children improve their lifestyle for being active.

During the resumption of school operation, prominent health organizations and public officials all over the world highly recommends to consider school as a venue for promoting active lifestyle (Ram et al., 2023). According to McQuinn et al., (2022) the school set up was considerably suitable for improving and managing students behavior towards being active. Children value their time on school therefore experience within the said place is crucial for their behavioral development (Nagy-Pénzes et al., 2022). Therefore, several studies were conducted regarding strategies on promoting physical activity, as well as evaluating the intervention program for sedentary lifestyle using school as its venue.

This review was driven by the impression that despite of numerous study and intervention conducted, global inactivity percentage continues to upsurge. With the researchers best of knowledge, thematic review paper is limited pertaining on patterns and trends of school strategies promoting physical activity during COVID-19 pandemic time.

Consequently, the aim of this study is to generate themes according to the issues and inclinations involved in the argument and discussion within the selected published article about school strategies in promoting active lifestyle during COVID-19 pandemic (2021 to 2023).

RQ: What are the concepts and trends about strategies implemented by school to improve physical activity engagement among students identified from the literature published year 2021 to 2023.

Materials and methods

Selected published articles were identified through following data base search 1. SCOPUS, 2. Sage, 3. ProQuest, 4. Academic search Complete and 5. Science Direct. Pattern was identified through the metadata transferred to ATLAS ti. 23 from Mendeley.

Thematic analysis is the process of recognizing and identifying new themes and patterns in iterative manner until deeply understanding the subject area (Braun & Clarke, 2008). Thematic review and analysis such as theme identification guided by ATLAS ti. 23 Mohd Zairul, (2020) was implemented in this study. This paper intends to explore the literatures conducted about school base strategies to improve active lifestyle during COVID-19 pandemic time for future reference on similar and related fields of researches.

This study set the following criteria for literature selection: 1) published from year 2021 to 2023; 2) full text published and 3) written in English language. Literature searched used physical activity, school, curriculum, intervention, strategy and COVID-19 as keywords. Data base search string used in SCOPUS, Sage, ProQuest, Academic search Complete and Science Direct was shown in table 1. Searching of articles was done December 22 to 23, 2023 which produced 1,212 literatures. SCOPUS data base generates 267 papers, 102 articles was identified through Academic search complete, Science direct identified 214 papers, 271 for Sage data base and 358 research work searched in ProQuest.

Published literatures generated from data base searched were downloaded being as the main data reference for this review article. Initial search identified 1,212 articles, followed by abstract screening that results exclusion of

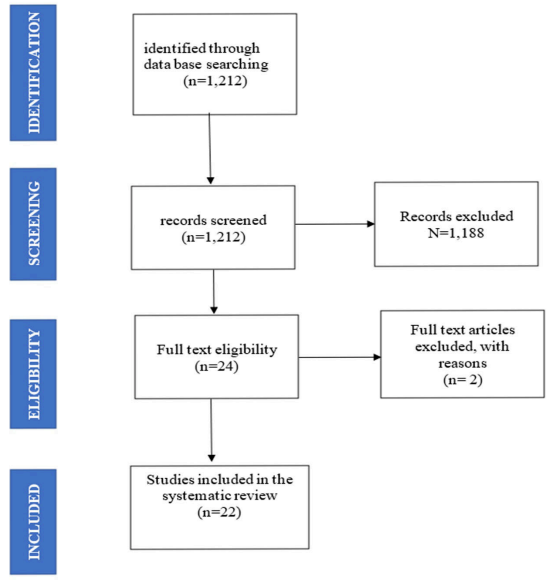

Fig. 1. Flowchart of literature selection

Table 1. Search strings from Scopus, Academic Search Complete, Science direct, Sage, ProQuest

Data Base	Search String	Result
SCOPUS	TITLE-ABS-KEY ("physical activity" "school" OR "curriculum" "covid" OR "pandemic" "strategy" OR "intervention") AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "english")) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (PUBSTAGE , "final"))	267
Academic Search Complete	"Physical activity" AND "school" AND "covid 19" AND ("strategy" OR "intervention")	102
Science Direct	"Physical activity" AND "school" AND "covid 19" AND ("strategy" OR "intervention")	214
Sage	"Physical activity" AND "school" AND "covid 19" AND ("strategy" OR "intervention")	271
ProQuest	"Physical activity" AND "school" AND "covid 19" AND ("strategy" OR "intervention")	358

1,190 literatures. Hence, resulting 22 documents included based on the inclusion criteria set in this study which will be the main data reference for further investigation (Figure 1). Selected documents were uploaded to ATLAS ti. 23 for thorough analysis. Quantitative approach was used to present and discuss the patterns and numerical features of the literature articles, publication dispersal by countries and themes identified during COVID-19 pandemic time (2021-2023). Moreso, identifying themes and concept, "coding, followed by categorizing and pattern recognition" was implemented during analysis phase, thus, making the investigation rigorous (Braun & Clarke, 2008).

Results and Discussions

Concept, themes and patterns generated are presented and discussed in this section. Research dispersal by country in which it was conducted, occurrence of words used in literatures included, frequency of publication during COVID-19 time (2021-2023) was included in quantitative report section.

Generating codes and identifying themes as well as concepts was guided by qualitative approach. Codes were identified within the selected literature during preliminary analysis. Accordingly, comparisons and links between the initial codes were further assess and analyze. Codes that were closely associated and share same concept with other codes were merge and recoded. After rigorous evaluation of preliminary codes, four main themes as well as concept and trends were identified using ATLAS ti 23 (Table 2).

Table 2. Thematic review of school practices to improve active lifestyle status of students during COVID-19 time (2021-2023)

Year	Alternative Physical Education	Physical literacy focus	Web based intervention	Needs based intervention	Total
2021	1	-	-	-	1
2022	3	1	2	1	7
2023	4	4	2	13	23
Total	8	5	4	14	31

Quantitative Report

Part of the review analysis was recognition of most word used in the paper selected in this study. This process offers preliminary notion about the concepts deliberated in the included articles for review. Text cloud using ATLAS ti. 23 generated the following words as most frequent used; "physical" (1,490) for most used by the literatures, then "school" which was mentioned 1,324 time, followed by "heath", "activity" and "intervention" with word count of 1,279, 1,184 and 1,123 respectively (figure 2).

Also included in quantitative report was the publication dispersal by countries conducted during COVID-19 pandemic time (2021-2023) as shown in figure three. Fifteen nations conducted and published their research about practices or interventions that aims to improve physical activity status of school students within the year 2021 to 2023. Six publications by the United States of America

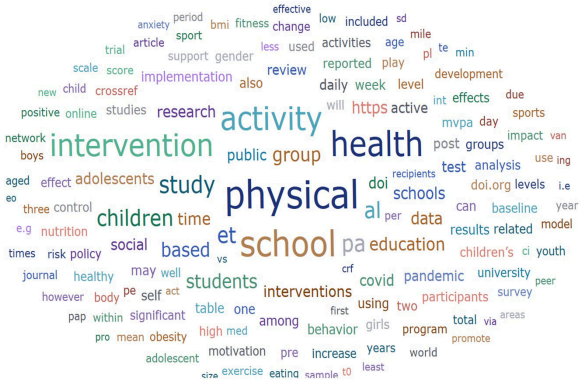

Fig. 2. Text cloud from the 22 articles included in the review

were the highest as per record, followed by Ireland and Italy conducting 2 researches, then single publication for the following nations; Hungary, Indonesia, China, Croatia, Germany, India, Netherland, Portugal, Sweden, Turkey, United Kingdom and Australia.

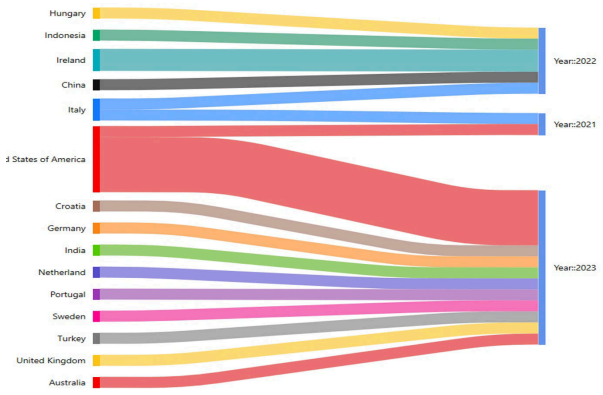

Fig. 3. Publication dispersal by countries conducted during COVID-19 pandemic time (2021-2023)

Practices implemented by schools during COVID-19 time was presented in table 2. Four main themes were generated in this paper through qualitative method. "Needs based intervention" was the most strategy used and evaluated by the researchers (14 times), followed by "alternative physical education" conducted 8 times, then activities that "focus on physical literacy" and web-based intervention being administered 5 and 4 times respectively. It is quite understandable that year 2023 has the most research conducted as schools around the globe during this year was back to its full operations.

Quantitative part of this study also involved the literature inclination to periodical in which it was published (table 3). Frontiers in Public Health has the greatest number of papers published within the period coverage having 3 acceptances. Followed by International Journal of Behavioral Nutrition and Physical activity and International Journal of Environmental Research and Public Health having 2 publications. Remaining periodicals published single literature within COVID-19 pandemic time duration. It was year 2023 that researchers conducted numerous studies regarding intervention using school as venue for change.

Table 3. Numbers of published paper per periodical (2021-2023)

Periodicals	2021	2022	2023	Total
Annals of Applied Science	-	-	1	1
BMC Public Health	-	-	1	1
Children	-	-	1	1
Dialogues in Health	-	-	1	1
Frontiers in Public Health	-	2	1	3
Frontiers in Sports and Active Living	-	-	1	1
Health Education Journal	-	1	-	1
Health Education Research	-	-	1	1
Health Promotion Practice	1	-	-	1
International Journal of Behavioral Nutrition and Physical activity	-	-	2	2
International Journal of Environmental Research and Public Health	-	1	1	2
Journal of Physical Education and Sport	1	-	-	1
Journal of School Nursing	-	-	1	1
Nutrients	-	-	1	1
Physical Education Theory and Methodology	-	1	-	1
Pilot and Feasibility Studies	-	1	-	1
PLoS ONE	-	-	1	1
Public Health and Nutrition	-	-	1	1
Total	2	6	14	22

Qualitative Report

Theme identification was performed through rigorous qualitative investigation. Identifying and sorting of themes, trends and concepts regarding school practices to improve the active lifestyle status of the school students during COVID-19 pandemic time were shown in figure 4. Preliminary coding generates 25 codes. Further evaluation of initial codes was performed, after thorough analysis, codes that links and share similar impression to other codes were merged and rename if necessary. After an in depth analysis of codes, 4 main themes were identified.

What are the concepts and trends about strategies implemented by schools to improve physical activity engagement among students identified from the literature published year 2021 to 2023?

Theme 1: Alternative Physical Education

Alternative Physical education was one of the central themes identified after rigorous analysis as shown in figure 5 depicting theme network and some selected quotation for presentation purpose. Seven literatures conducted and evaluated an approach to improve students' physical activity engagement performed in schools during pandemic (COVID-19) time.

COVID-19 provides major transformation in students daily life. Not only in some countries but across the globe (Marenus et al., 2023). Movement restriction and social distancing hinders physical activity engagement. Also, school closure contributes to inactivity of children which is considered as a problem (Samsudin et al., 2022). Hence, campaign against sedentary lifestyle of the students was put into consideration by the school upon its resumption. However, due to the changes brought by COVID-19, school curriculum and instruction were affected. Therefore, alternative approaches that is suitable to the needs of current situation was put into consideration.

Several activities and program were conducted by the researcher in coordination of school. Children spends most of their time within the school, therefore it was noteworthy to consider its effectiveness as the venue for intervention regarding sedentary behavior. According to (Ram et al., 2023), curriculum and instruction is a significant factor for intervention as it is designed for students. Physical education subject was one of the key factor researchers are looking into. Thus, to fit into the current global situation, approach was made some modification.

"Physical education on the beach" was one among the alternative approach conducted and evaluated. According to Gallotta et al. (2022) outdoor activities can motivate students to engage in physical activity because "open space" can lessen that possibility of the virus spread during the activity. Similarly, physical activity engagement was evaluated through the concept of "schoolyard". School open space provides increase physical activity among students (Hazlehurst et al., 2023). Furthermore, study about "urban outdoor education" was reported to have significant impact on kids active behavior (Borgogni & Agosti, 2021). Outdoor education provides enjoyment and captures students interest even during COVID-19 pandemic time. Another activity concept that categorizes as alternative physical education was promoting active lifestyle through "real-world" context. However, measure of success of this study was reported to be affected by COVID-19 restrictions. Lastly, "games-based" approach by Murphy et al. (2022) which was alternatively performed during break specifically at lunch which concluded to have positive impact on students well-being.

Alternative physical education as an approach to improve student's active lifestyle was a promising idea. It gains the interest of the children, therefore being motivated to participate. However, crafting and designing of the program or activities must consider all of the factor concerning health and other risk aspect by the participants. Moreso, it was suggested that physical activity must be comprehensive to attain greater result (Gallotta et al., 2022). Sustainability was also emphasize in terms of strategies or intervention to be conducted (Ram et al., 2023).

Theme 2: Physical literacy focus

Physical literacy is a complex foundation of an individual from awareness and understanding to know-how of physical activity engagement as part of life cited by (Gilic et al., 2023). Physical literacy can be the major goal of physical educators and be included in the on the objectives on other health related field. "Physical literacy focus" is one among of the four main themes generated in this review. Five papers included in this study deals with the concept of physical literacy as strategy or intervention for sedentary lifestyle. Figure 6 shows the network of theme 2 identification.

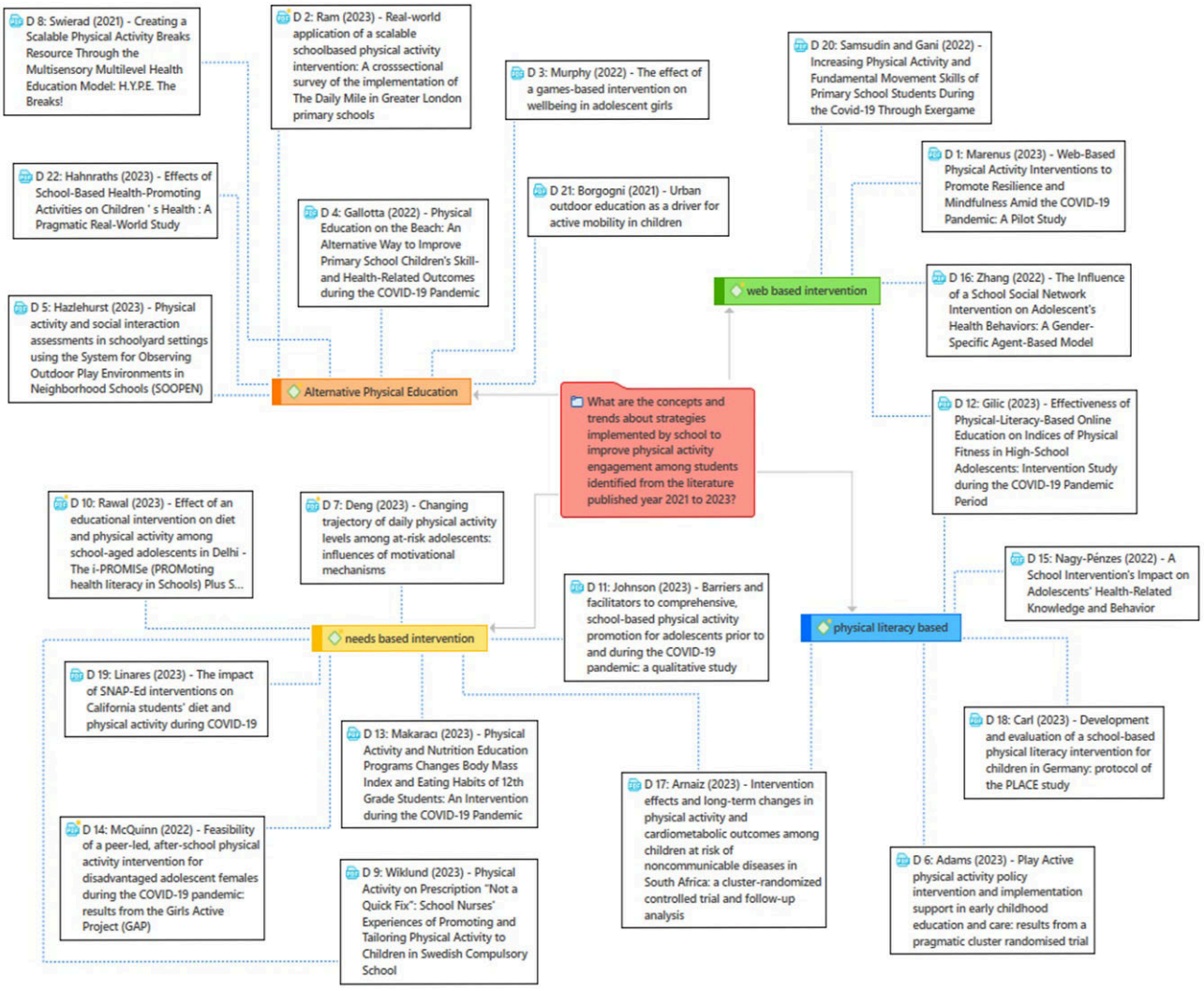

Fig. 4. General network for theme identification within selected literature

This approach is about providing awareness and knowledge about physical activity engagement which aims to provide motivation to the participants as a result. Notable result was reported through this strategy as physical fitness improved among middle school students after a series of imparting knowledge about physical literacy through video (Gilic et al., 2023). However, shows no significant impact on skills development. Similarly, Nagy-Pénzes et al. (2022) focus on the information advancement on active lifestyle and put emphasis on the factor that the intervention approach was part of the school program, resulting into a positive impact as the students made progress on familiarity about health-related perception and attitude. Yet, it was emphasized that awareness must be accompanied by another possible factor to achieve behavioral modification (Nagy-Pénzes et al., 2022).

Disseminating information about physical activity especially during this COVID-19 pandemic era is very important. Full understanding on the its positive impact will help the society to cope up with negative vibes brought by the virus spread. According to Carl et al. (2023), physical literacy is a significant concept to anchor with by intervention approach for children. Moreso, suggested that respective authorities must design their programs within the physical literacy principle. This was backed up by the study findings that getting support by including the program within the scope of plans and policy was an advantage (Adams et al., 2023).

Theme 3: Web-based intervention

Web based intervention is a method that focus on a technological device and cyberspace as an instrument to implement modification aimed by the activities included in intervention. Four published articles focus on technology as the medium of the change they want to evaluate. Figure 7 shows the thematic analysis network of this theme together with selected quotations for presentation.

Intervention that uses virtual physical activity instruction is among the approach evaluated. According to Marenus et al. (2023) teaching physical activity through cyberspace have positive impact on students overall awareness but not in terms of mental toughness. However, improvement on physical activity engagement was not identify in the study.

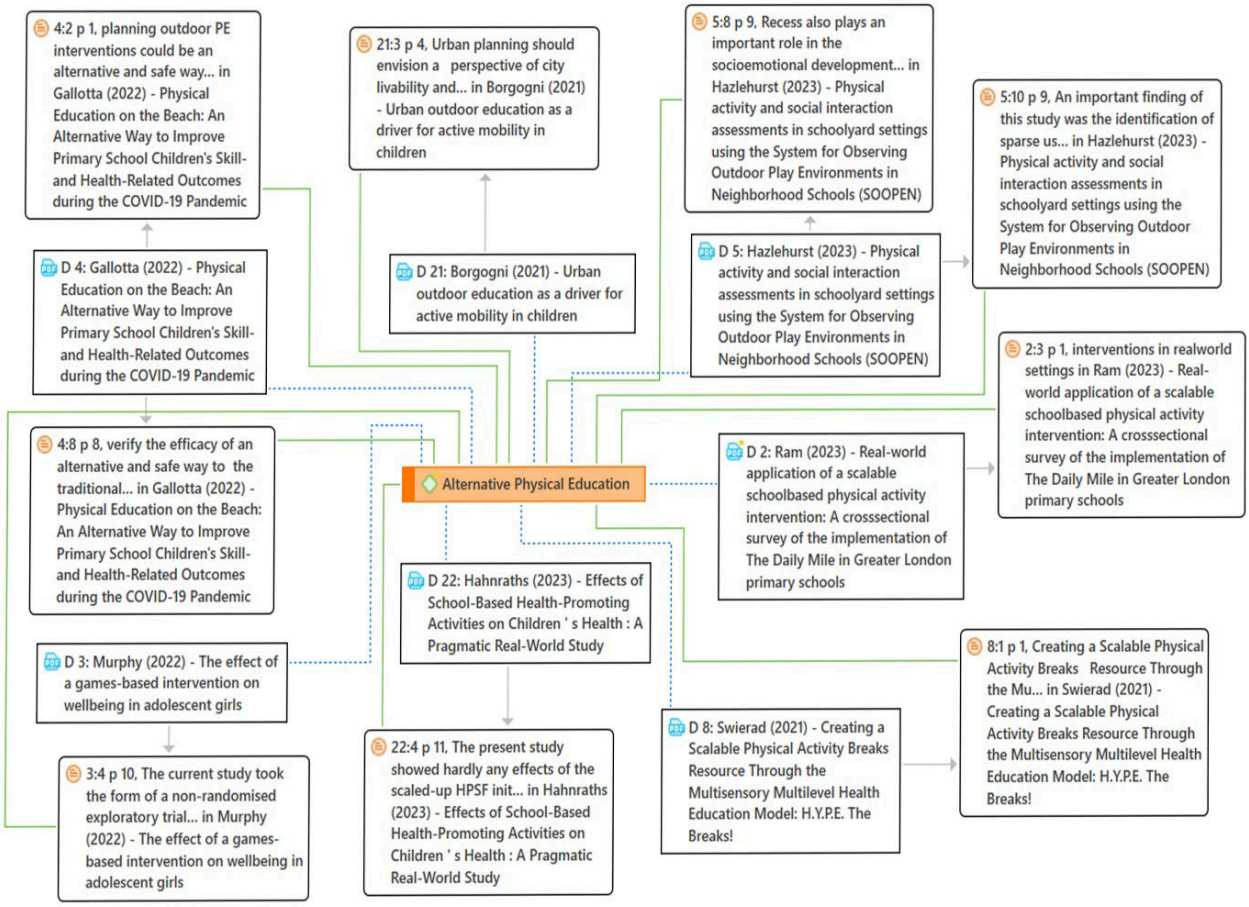

Fig 5. Network of Alternative Physical Education theme

On the study conducted by Gilic et al. (2023) intervention approach was designed video clip presentation and cited improvement on some aspects of physical fitness. Similar approach was used by Zhang et al. (2022) on their study which assess the impact of "social network intervention" on middle school students perception on well-being which concluded that results differ when group by gender. Hence, suggesting to incorporate gender sensitivity to a program when crafting or designing. Another interesting approach included in this theme is the "exergame". According to Samsudin et al. (2022) this gains the interest of the participants because of the enjoyment associated to it. This web-based approach was concluded to have a positive effect on the fundamental movement skill among students.

COVID-19 provides a lot of change in community lifestyle. Society became cautious in every activity they need to participate. Web-based intervention program seems to be suitable to the needs provided by the current situation. Virtual activities can be done at home, therefore, decreasing the risk associated to COVID-19. Behavioral change can be attained at home through internet based activities (Samsudin et al., 2022).

Theme 4: Needs-based intervention

In depth review analysis generates "needs-based intervention" among of the four main themes (Figure 8). This theme refers to the approach that was specifically designed to the target population. The intervention considers the characteristics of students that could possibly affect intervention results.

According to Wiklund et al. (2023) accomplishing the intended results for intervention was greater when the activity was specifically created for children perception and behavior. In their study that focus on active play engagement for children, they emphasized the significance of individualization of program. Furthermore, concluding that their approach gains kids interest and must be a long-term process. Some approach included in this theme focused on the dietary and physical activity needs of the participants. Makaracı et al. (2023) concluded in their study that awareness on the positive effect of movement as well as on dietary recommendation is beneficial to students during COVID-19 era. Similarly, Linares et al., (2023) conducted their approach aiming students nutrition and inactivity. Their approach was tailored to the students' attributes regarding nutrition and being active. According to Rawal et al. (2023) school based intervention on students behavior towards food and active play participation resulted significant impact, however, suggesting to have a program that is more inclusive. To be effective, activities included in the program must consider all factors; from strategies to implementers (Johnson et al., 2023).

Needs-based intervention is very important especially when dealing to a participant that is consider as "at risk". All security measures must be well incorporated to the activities

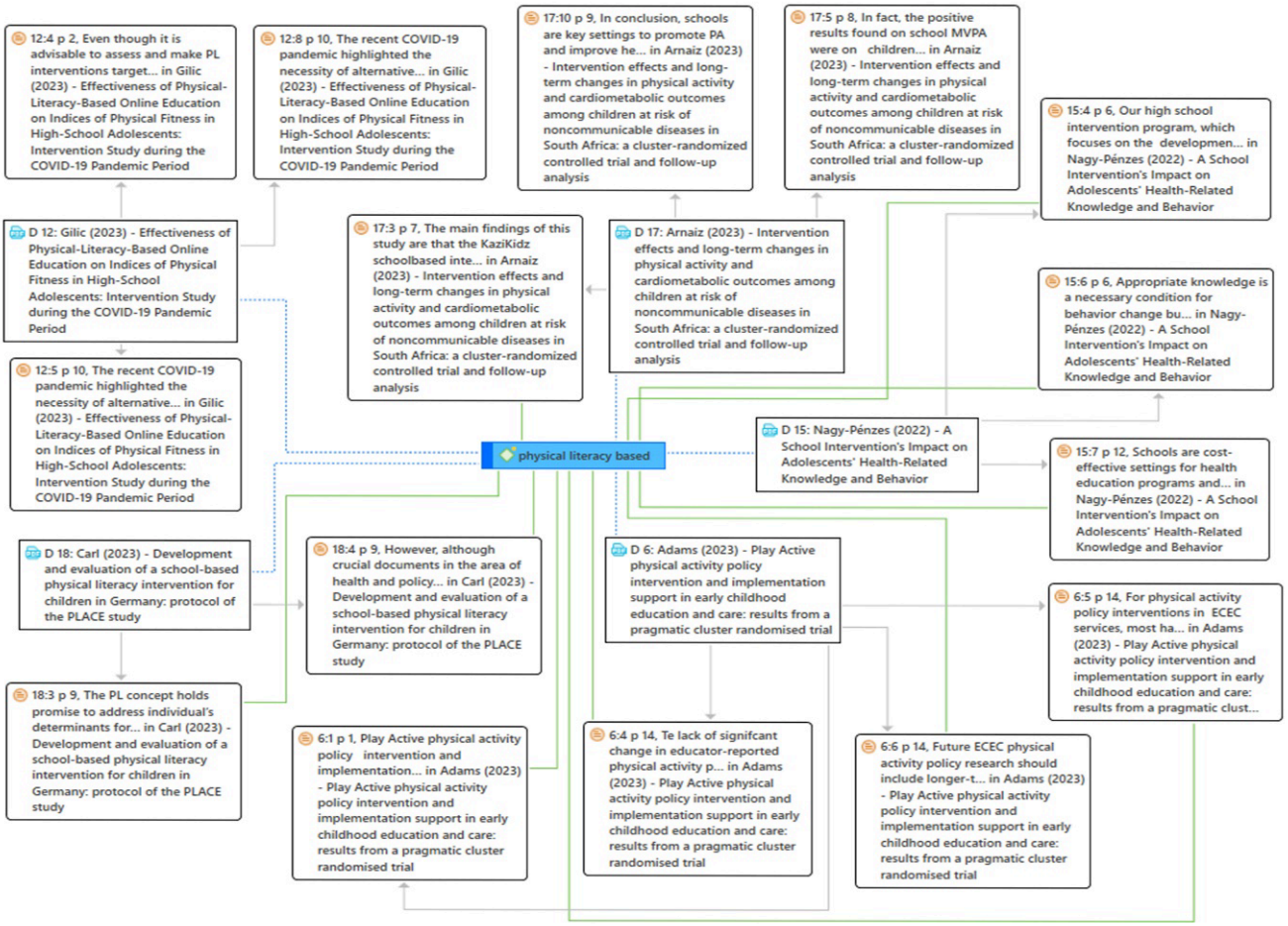

Fig. 6. Network of Physical literacy focus theme

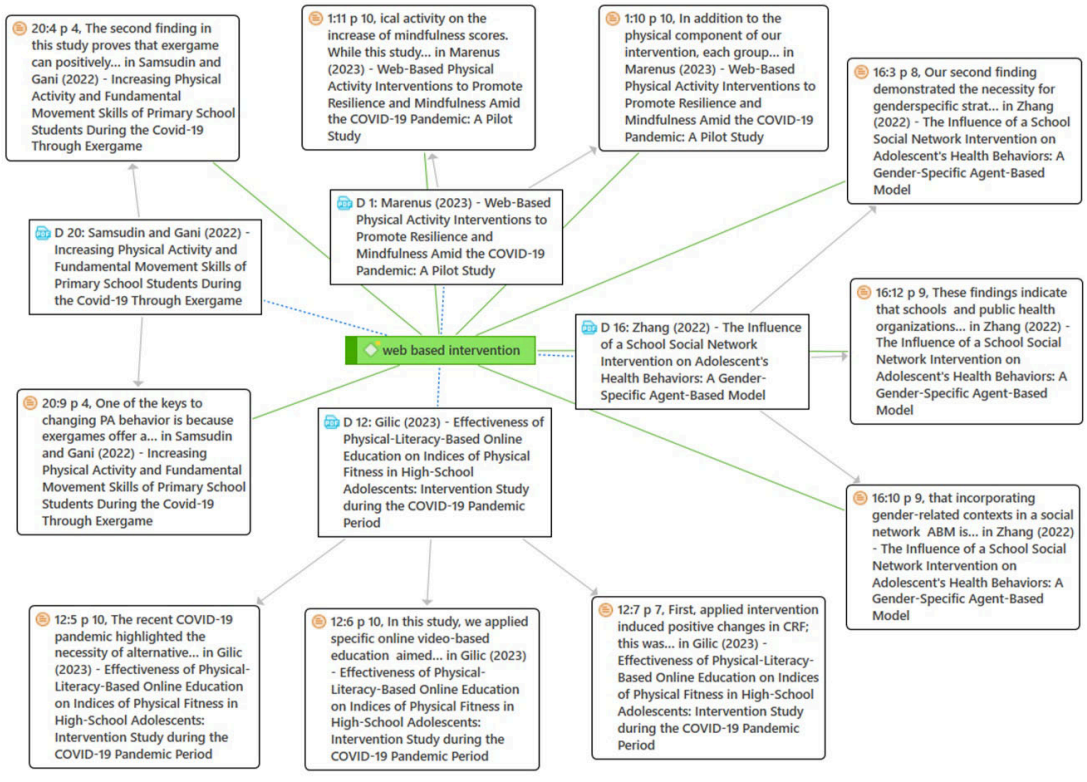

Fig. 7. Network of web-based intervention theme

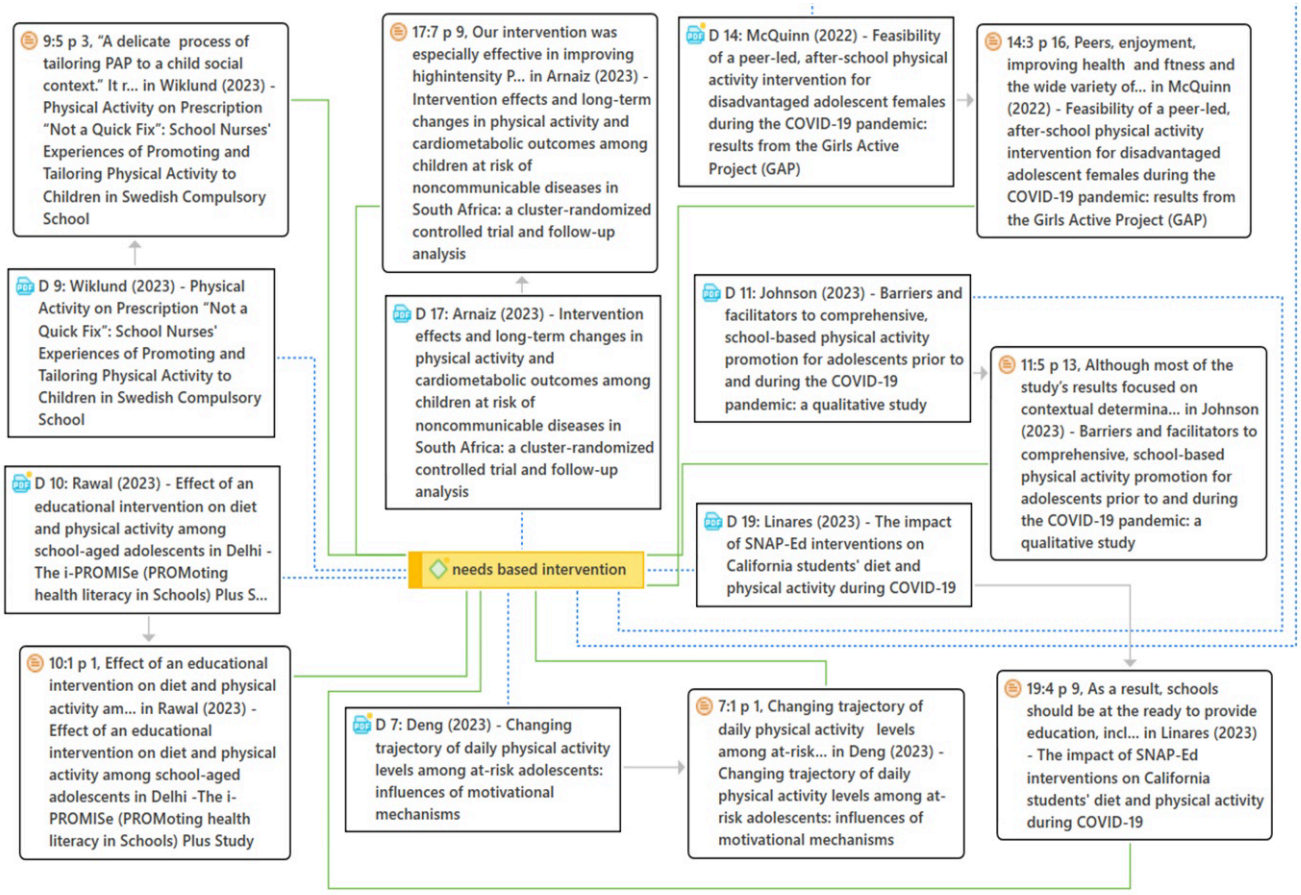

Fig. 8. Network of Needs-based intervention theme

included. Arnaiz et al. (2023) conducted intervention program to students with "cardiometabolic risk". They concluded that the approach has positive effect on physical activity and "cardiometabolic factor". In line with needs based intervention, it was suggested that to prevent inactivity and enhance wellbeing, modifications anchored to the target populations need must be emphasized for greater possibility of its success (Arnaiz et al., 2023).

Conclusions and future studies

COVID-19 pandemic draws a lot of changes in the society. Precautionary measures such as movement restriction and social distancing provides lifestyle modification. Sedentary lifestyle among children was one of the adverse effects associated to pandemic'19. School contribution on improving student's lifestyle was stopped because of its temporary closure. Therefore, health practitioners and other allied professionals conducted and evaluated school-based strategies that aim to improve students' physical activity upon its resumption.

Published literatures encompasses several school-based intervention approaches. Strategies were greatly affected by the current health situations. "Alternative Physical Education" was done in open space as part of being cautious. Also, this approach was anchor to the concept of gaining more motivation compare to traditional physical education subject. Generation of "Physical literacy focus" was a significant concept to consider. This suggest that the approach must tackle the multi dimension foundation in physical activity engagement. Physical literacy awareness must be included in the program objective as well as in policy for its greater result. "Web based" intervention is a timely mode of activity delivery to attain the desired behavioral changes. Safety measures among students are considered because it can be done at home. Moreso, technology is considered as part of daily life for young populations. Another significant theme generation of this study was "needs-based intervention", this focus on the strategy which must be specifically tailored to the target population. Although this requires a lot of work, achieving success was greater in possibility. Future works may deal on the research gap provided and identified by previous literatures and may result for another approach. Inclusions of data base in document gathering to be use as the main source of information in this review was consider as its limitation; upcoming research to a greater extent can consider different archives and data bases.

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Conflict of interest

Authors state no conflict of interest.

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Стратегії шкільної освіти щодо поліпшення залучення учнів до фізичної активності під час пандемії COVID-19: тематичний огляд

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 10 с., 3 табл., 8 рис., 24 джерела.

Мета дослідження. Впродовж останнього десятиліття проблема відсутності фізичної активності серед школярів становила значну небезпеку для здоров'я. Ситуація загострилася, коли світ вразила пандемія COVID-19. Обмеження пересування, що призводить до тимчасового закриття шкіл, суттєво впливає на залучення учнів до фізичної активності. Тому стратегії та практики, спрямовані на поліпшення залучення до активної ігрової діяльності, а також на протидію її негативному впливу на здоров'я учнів, були широко впроваджені вчителями та адміністрацією шкіл після їх повторного відкриття. Було опубліковано численні статті про ефективність впровадження інтервенцій на базі шкіл під час пандемії COVID-19, але досі бракує оглядового дослідження, спрямованого на виявлення закономірностей і тенденцій щодо впровадження шкільних практик у цій сфері. Таким чином, цей матеріал має на меті сформувати уявлення та визначити концепції в рамках опублікованих статей протягом 2021-2023 років.

Матеріали та методи. Статті для цього дослідження були відібрані з наступних наукометричних баз даних: SCOPUS, Sage, ProQuest, Academic Search complete, Science Direct. Для забезпечення комплексності цього огляду було застосовано аналіз якісних даних за допомогою комп'ютерних програм (ATLAS ti. 23). Результати дослідження були сформовані та представлені за допомогою кількісної та якісної оцінок.

Результати. У дослідженні було визначено чотири головні теми: 1) Альтернативна фізична культура – модифікація традиційного предмета фізичної культури; 2) Фокус на фізичну грамотність – підхід, заснований на багатовимірній основі залучення до фізичної активності; 3) Веб-орієнтована інтервенція – підхід, заснований на віртуальному та кіберпросторі; 4) Інтервенція, орієнтована на потреби – фокусується на інтеграції характеристик учасників та спеціально розробленої програми.

Висновки. На структуру стратегій, що реалізуються школами, значною мірою впливає поточний стан здоров'я громади. Результати цього дослідження слугуватимуть орієнтиром для розробки майбутніх інтервенційних підходів до вирішення проблеми малорухливого способу життя молоді, пов'язаного з певними проблемами здоров'я громади та іншими суміжними питаннями.

Ключові слова: школа, інтервенція, фізична активність, ATLAS ti. 23, COVID-19.

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REVIEW ARTICLE

Phytochemical Compounds in Sea Cucumber Have the Potential to Reduce Oxidative Stress and Inflammation Due to Exercise: Systematic Review

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Abstract

Study purpose. This study aims to analyze and highlight the potential of Sea Cucumber in reducing oxidative stress and inflammation caused by exercise.

Materials and methods. The study is a type of systematic review research using searches from various journal databases such as Science Direct, Pubmed and Web of Science. The inclusion criteria in this study were journals published in the last 5 years which discussed sea cucumber, oxidative stress, inflammation and exercise. Furthermore, the exclusion criteria in this research are journals that are not reputable or are not indexed by Scopus and Web of Science. A total of 1038 articles from the Science Direct, Pubmed and Web of Science databases were identified. A total of 8 articles that met the inclusion criteria were selected and analyzed for this systematic review. For standard operations, this study followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) assessment.

Results. The results of this systematic review research report that the strong phenolic content found in Sea Cucumber has anti-oxidant properties which may reduce oxidative stress. Furthermore, the anti-inflammatory properties of sea cucumbers have the potential to reduce uncontrolled inflammation caused by intense exercise.

Conclusions. The phenolic content in sea cucumbers has strong anti-oxidant properties in reducing oxidative stress. In addition, the anti-inflammatory properties of sea cucumbers may reduce uncontrolled inflammation caused by exercise. In this case, sea cucumbers have an anti-inflammatory effect by suppressing the secretion of pro-inflammatory cytokines. Through this systematic review, we recommend that future studies should perform clinical trials on the potential effects of sea cucumber on oxidative stress biomarkers and inflammatory biomarkers after exercise.

Keywords: sea cucumber, oxidative stress, inflammation, exercise.

Introduction

Regular physical exercise with light to moderate intensity is the main factor in preventing various diseases such as cardiovascular, diabetes, cancer, alzheimer's and dementia (Tian and Meng, 2019; Cannata et al., 2020). With physical activity, anaerobic and aerobic metabolism and energy requirements by active muscles increase (Taherkhani, Suzuki and Castell, 2020; Daniela et al., 2022). However, intense physical exercise can cause significant damage to skeletal muscle tissue leading to decreased muscle function performance (Ayubi, Kusnanik, Herawati, Muhammad, et al., 2023). To save muscle

performance through the immune system, an increase in the pro-anti/inflammatory balance is carried out which allows muscle regeneration (Volpe-Fix et al., 2023).

Another consequence, triggering changes in redox reactions in the immune system during muscle strength training can occur through neutrophil infiltration into damaged tissue, thereby causing increased oxidative stress and inflammation (Canals-Garzón et al., 2022). Oxidative stress occurs approximately one hour after exercise, characterized by an increase in reactive oxygen species (ROS) (McKeegan et al., 2021). In the next phase, exercise-induced muscle damage (EIMD) and increased ROS will trigger inflammation and reach its peak 24-48 hours after exercise (Chang et al., 2021; Hung et al., 2021). The inflammatory response due to exercise triggers a decrease in muscle strength, decreased range of motion (ROM), delayed onset muscle soreness (DOMS), local swelling, and an increase in muscle proteins in the blood (creatine kinase (CK), lactate dehydrogenase (LDH), and myoglobin (Mb) (Fernández-Lázaro et al., 2020; Tanabe, Fujii and Suzuki, 2021). In addition, EIMD triggers an inflammatory reaction that causes an increase in inflammatory markers such as C-reactive protein (CRP) and several inflammatory interleukins (IL-1 and IL-6) and tumor necrosis factor alpha (TNF-α) (Kyriakidou et al., 2021; Nejati et al., 2022). In the same way, this promotes the synthesis of ROS, which ultimately stimulates the development of transcription factors including nuclear factor kappa Beta (NF kB) which plays an active role in the secretion of TNF-α (Fern and Mielgo-ayuso, 2020). Use of nonsteroidal anti-inflammatory drugs (NSAIDs) is estimated at 30 million people worldwide, with a high prevalence among athletes and individuals performing high-intensity exercise (Kyriakidou et al., 2021). However, clinical data suggest that administration of nonsteroidal anti-inflammatory drugs after resistance training has a detrimental effect on recovery after EIMD (Ayubi et al., 2022; Ayubi, Kusnanik, Herawati, Komaini, et al., 2023).

Therefore, alternative solutions are needed to overcome this problem as a potential treatment. One natural product that can be used, with potential anti-inflammatory antioxidant effects is sea cucumber. Sea Cucumber is an invertebrate animal that belongs to the phylum Echinodermata. This species is rich in bioactive compounds that have various biological and pharmacological properties such as antioxidant, wound healing, anticoagulant, anti-cancer, anti-tumor, antibacterial, anti-inflammatory effects, improving hyperlipidemia, and regulating blood sugar (Zhao et al., 2018; Hossain et al., 2022; Rasyid, Putra and Yasman, 2023). The bioactive compounds contained in sea cucumbers include saponins, phenolics, proteins (peptides), carotenoids and lipids (Hossain, Dave and Shahidi, 2020). Based on research, it has been reported that the phenolic compounds in sea cucumbers act as antioxidants which can prevent or reduce oxidative stress in cells, prevent aging and play an important role in controlling various diseases, especially cardiovascular disease, inflammation and cancer (Hossain et al., 2022; Hossain, Dave and Shahidi, 2022; Senadheera et al., 2023). Phenolics can inhibit the synthesis of pro-inflammatory cytokines, especially inducible nitric oxide synthase (iNOS), nitric oxide (NO), TNF-α, interleukin-1β (IL-1β), and prostaglandin E2 (PGE2) (Hossain et al., 2022). The antioxidant activity in these phenolic compounds can help reduce oxidative damage due to exposure to high levels of UV radiation and reactive oxygen species (ROS) by donating electrons or hydrogen atoms to free radicals to inhibit free radical chain reactions (Hossain et al., 2022; Rasyid, Putra and Yasman, 2023). Therefore, we want to relate and discuss in depth the effect of using sea cucumbers in reducing oxidative stress and anti-inflammation after exercise through a systematic review.

This study aims to analyze and highlight the potential of sea cucumbers in reducing inflammation and inflammation due to exercise.

Materials and methods

Study Design

This type of systematic review research uses searches from journal databases such as Science Direct, Pubmed, and Web of Science. It is considered a premier platform worldwide as it brings together publications that have scientific impact and relevance.

Eligibility criteria

The inclusion criteria in this study were journals published in the last 5 years that discussed sea cucumber, oxidative stress, inflammation and exercise. Furthermore, the exclusion criteria in this research are journals that are not reputable or are not indexed by Scopus and Web of Science.

Procedure

Titles, abstracts and full texts of articles were filtered and then stored in Mendeley software. In the first stage, 1038 articles from the Science Direct, Pubmed and Web of Science databases were identified. Next, in the second stage, 186 articles were screened based on the suitability of the title and abstract. In the third stage, 36 articles were ordered for further processing. At this stage we filter based on the overall suitability of the article. Then in the final stage 8 articles were selected that met the inclusion criteria and analyzed for this systematic observation. For operational standards, this study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) assessment.

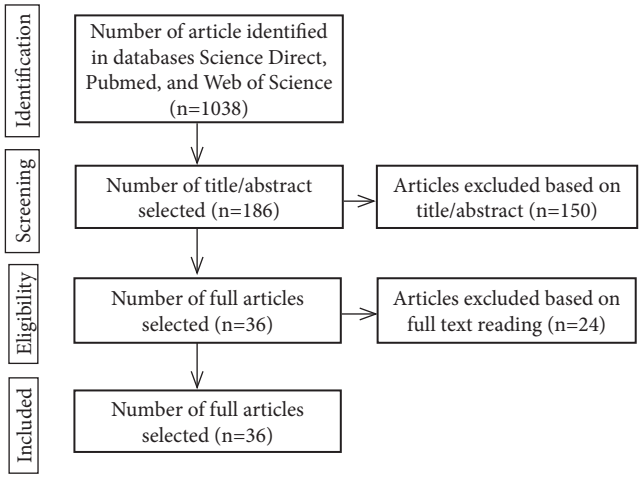

Fig. 1. PRISMA flowchart of the article selection process

Results

Table 1. Results of a review of the effects of sea cucumbers on oxidative stress and inflammation due to exercise

Author	Sample Characteristics	Study Design	Intervention	Results
Q. Wang et al. (2021)	Male ICR mice weighing 20 g were grouped into 6 groups, namely (1) negative control group, (2) whey peptide group, (3) low dose SCP-1 (peptide derivative) group, (4) high dose SCP-1 group, (5) low dose SCP-2 group, (6) high dose SCP-2 group.	Experimental	Peptides derived from sea cucumbers were characterized and then samples were given orally to mice for 30 days. After that, training and anti-fatigue performance of the two bioactive peptides (SCP-1 and SCP-2) were tested through a 30-minute swimming test combined with monitoring biochemical parameters (serum indicators BUN, LDH, NH3, and CK; liver indicator LG ; and muscle indicators SOD, MDA, MG, ATP).	Supplementation of bioactive peptides from sea cucumbers, namely SCP with low DH (SCP-1) and SCP with high DH (SCP-2) is reported to improve exercise performance and show anti-fatigue effects through inhibiting oxidative stress by regulating the NRF2 and AMPK signaling pathways that contribute to physical fatigue relief performance. In addition, the effect of SCP has the potential to protect muscles from muscle injury by significantly reducing LDH and CK levels. This SCP supplement effectively reduces MDA levels.
P. Wang et al. (2021)	Male Sprague Dawley (SD) rats weighing 180-220 g were grouped into 6 groups, namely: (1) normal control group, (2) model control (MC) group, (3) low dose SCP (peptide derivative) group, (4) medium dose SCP group, (5) high dose SCP group, and (6) positive control (PC) group.	Experimental	Peptide samples originating from sea cucumbers were characterized and then the samples were given orally to mice for 4 weeks. After that, sports performance and anti-fatigue testing were carried out through a 150minute swimming test combined with biochemical parameter monitoring (serum indicators BUN, LDH, NH3, and CK; liver indicator LG; muscle indicators SOD, MDA, MG, ATP), analysis of inflammatory cytokine levels (serum TNF-α, IL-1β, IL-6, and IL-10 levels).	Peptide supplementation from sea cucumbers in this study had high antioxidant activity due to the amino acid content in SCP. SCP can significantly increase liver glycogen, increase muscle glycogen, decrease BLA, decrease BUN, decrease CK, increase SOD, increase GSH-px, increase CAT, decrease MDA, decrease TNF-α, decrease IL-1β, decrease IL-6, and reduces NF-κB so that this supplement can reduce levels of oxidative stress, anti-inflammatory and anti-fatigue after physical exercise.
Yu et al. (2020)	Male mice weighing 33 g were grouped into 4 groups, namely a group of control mice, a group of mice fed a low dose of SCP (peptide derivative), a group of mice given a medium dose of SCP, and a group of mice given a high dose.	Experimental	Subjects were given bioactive peptide supplements from sea cucumbers (SCP) according to the dosage. Then, endurance and anti-fatigue performance were tested through a 1hour swimming test. And samples of these organs were taken to measure biochemical indicators related to fatigue and tissue damage after physical exercise.	Peptide supplementation in sea cucumbers (SCP) significantly increases antioxidant capacity. The results of physiological indicators related to fatigue showed that LD and BUN decreased significantly, followed by LDH and GOT which also decreased. Administration of SCP can increase anti-fatigue properties through improving mitochondrial quality which is useful for antioxidant capacity.

Table 1. Continued

Author	Sample Characteristics	Study Design	Intervention	Results
Wang et al. (2023)	40 male diabetic Sprague Dawley (SD) rats and 10 normal rats weighing 120-150 g were grouped into 5 groups and given the following treatment: (1) normal control group, (2) diabetic control group, (3) 250 mg metformin group /kg, (4) low dose SCH group 200 mg/kg, (5) high dose SCH group 400 mg/kg.	Experimental	Subjects were given Sea Cucumber Hydrosylate (SCH) and dissolved in normal saline orally for 8 consecutive weeks. Then biochemical testing of urine and plasma was carried out to test U-MA, SOD and MDA levels.	SCH supplements can reduce U-MA and reduce inflammatory disorders. Administration of SCH is reported to restore SOD, GSH, MDA levels which can effectively reduce oxidative damage. SCH also helps maintain increased antioxidant capacity through the Akt/Nrf2/NQO1 signaling pathway thereby reducing oxidative stress in the kidneys.
Carletti et al. (2022)	208 fresh sea cucumbers and tunicates were prepared then the samples were dried and ground into fine powder. Then it is extracted to become an extract and chemical testing is carried out.	Laboratory experiments	The prepared samples of sea cucumbers and tunicates were dried and processed until they became powder. Then extracted using an ethanol-water mixture. The extract was tested for its antioxidant and anti-inflammatory activity.	It was reported that sea cucumber and tunicate extracts as a source of bioactive compounds have high polyphenol content so they have potential for antioxidant and anti-inflammatory activity.
Aatab et al. (2023)	A 200 g sample of dried sea cucumber (H. tubulosa) was suspended in a phosphate buffer solution to form aqueous extracts (AEs). Then analyzed further for chemical and morphological characterization, total phenolic content, and antioxidant capacity.	Laboratory experiments	The sea cucumber specimens were dried first. Then the dry samples were ground and 200 g of dry samples were suspended in 400 mL of phosphate buffer solution for 3 and 4 hours to produce a supernatant and dried by spray and freeze drying to produce aqueous extracts (AEs) for further analysis. After that, chemical and morphological characterization tests were carried out, total phenolic content and antioxidant capacity were carried out on the sea cucumber extract.	All sea cucumber AE samples have similar characteristics which indicate a high content of phenolic compounds (gallic acid, pyrogallol, pyrogallic acid, vanillic acid) and flavonoids (quercetin, vanillin, routine, kaempferol) which have the potential to ward off free radicals so that they can contribute as antioxidants and anti-oxidants. -inflammation.
Wargasetia et al. (2023)	20 g of sea cucumbers were ground into powder and then extracted with methanol. Sea cucumber extracts were tested for antioxidant and anti-inflammatory activity.	Laboratory experiments	The sea cucumber sample powder was extracted using 500 mL methanol for 48 hours. The macerate is filtered and the filtrate is evaporated at a temperature of 50°-60°. Sea cucumber extract was mixed with DPPH and incubated for 30 minutes. Then antioxidant and anti-inflammatory activity tests were carried out.	The sea cucumber extract in this study showed the presence of active compounds that have strong activity against NO radicals so that they have potential as antioxidants and anti-inflammatory. Apart from that, the active compounds in sea cucumber extract also have the potential to inhibit the KEAP1 and iNOS proteins which cause oxidative stress and inflammation.

Table 1. Continued

Author	Sample Characteristics	Study Design	Intervention	Results
Ghaffari et al. (2019)	Samples of sea cucumbers that were in powder form were extracted to become extracts. Then, 30 Wistar-albino rats weighing 160-180 g were divided into 5 groups, namely: control group, treatment group with carrageenan, extract treatment group with a dose of 100 mg/kg MEHL and carrageenan, extract group with a dose of 200 mg/kg MEHL and carrageenan, the acetylsalicylic acid and carrageenan group. Then, the extract is given orally for 1 hour before carrageenan injection.	Experimental	The sea cucumbers were dried and extracted with a solution of hexane, ethyl acetate and methanol for 72 hours. Then, the sea cucumber extract was tested orally on 30 mice 1 hour before the carrageenan injection. For 5 days, inflammation was measured in the mice and the inflamed paw tissue was removed and tested for further analysis.	Sea cucumber extract shows a decrease in the inhibitory power of the lipoxygenase enzyme which causes inflammation. This is due to the presence of phytosterol compounds in it. So this extract is proven to have anti-inflammatory effects.

Discussion

The main research objective of this systematic review is to analyze and highlight the potential of sea cucumbers in reducing oxidative stress and inflammation due to exercise. Sea cucumbers are invertebrates belonging to Kingdom: Animalia; Phylum: Echinoderms; and Class: Holothuroidea. Sea cucumbers have a soft body, like a cucumber with an elongated tube-like body shape, and a single-branched gonad. The mouth is surrounded by tentacles/bulbs at one end of the body and the anus at the other end (Figure 2). The most commonly found species of marine biota include Holothuria tubulosa, Pearsonothuria graeffei, Isostichopus badionotus, Holothuria nobilis, Holothuria polii, Holothuria forskali, Cucumaria japonica, Cucumaria frondosa, Actinopyga mauritiana, Acaudina molpadioides, and Apostichopus japonicas (Kareh et al., 2018; Hossain, Dave and Shahidi, 2020; Aatab et al., 2023; Wargasetia et al., 2023).

Sea cucumbers can produce various useful natural ingredients, including for the food industry, cosmetics industry, and agricultural industry, and treat various diseases such as rheumatism, asthma, pain, hypertension, wounds, burns and kidney problems (Kustiariyah, 2007; Hossain, Dave and Shahidi, 2022). Sea cucumbers are known for their therapeutic potential which is rich in protein (40-60%), and low in fat (calcium, zinc, iron, and magnesium), vitamins and minerals. In addition, sea cucumbers are known to contain various bioactive compounds, such as polysaccharides, collagen and peptides, sphingoids, phenolics, triterpene glycosides (saponins), sterols, carotenoids, and chondroitin, which exhibit various biological and pharmacological functions such as antimicrobial, antioxidant , antihypertensive, immunoregulatory, anti-inflammatory, anticoagulant, anticancer, antidiabetic, antifatigue, antiaging, and antithrombotic which can be seen in Figure 3 (Suwanmala et al., 2016; Hossain, Dave and Shahidi, 2020, 2022; Yu et al., 2020; Q. Wang et al., 2021; Hossain et al., 2022; Senadheera et al., 2023).

It has been found that the content of phenolic compounds, proteins (collagen and peptides), carotenoids,

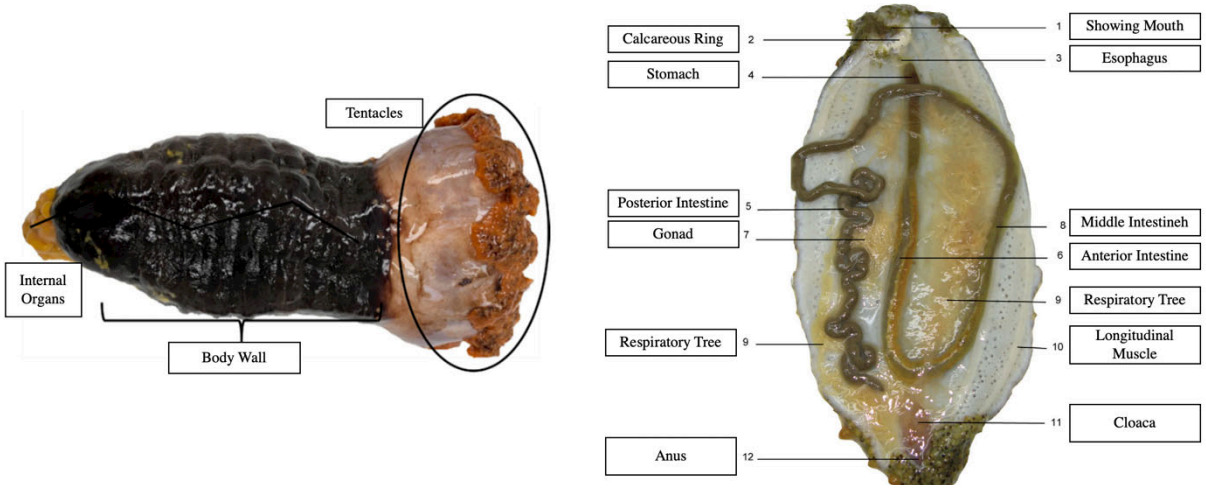

Fig. 2. Sea Cucumber Anatomy

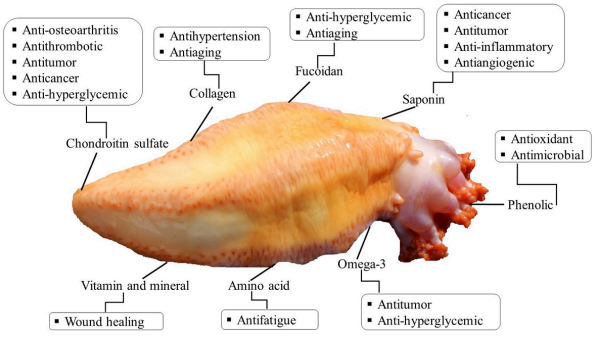

Fig. 3. Bioactive Compounds of Sea Cucumber and Their Potential Health Benefit (Hossain, Dave and Shahidi, 2020)

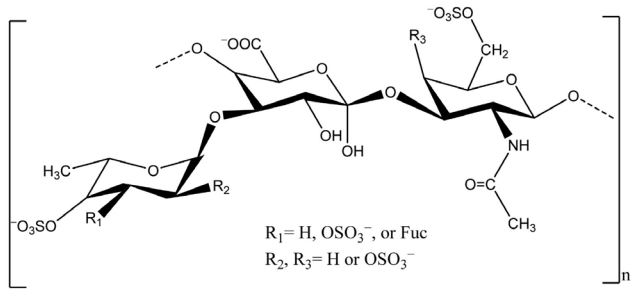

Fig. 5. Chemical structure of polysaccharides (fucosylated chondroitin sulphate, FCS) and fucan of sea cucumbers (Hossain, Dave and Shahidi, 2020)

and saponins have strong antioxidant properties, with their chemical structures which can be seen in Figure 4 and Figure 5. Antioxidants are responsible for scavenging free radicals thus preventing oxidation. Antioxidant activity can be attributed to the presence of phenolic content in sea cucumbers (Hossain, Dave and Shahidi, 2022). Phenolics act as scavengers of various oxidizing species namely superoxide anions, hydroxyl radicals, or peroxy radicals, they also act as singlet oxygen scavengers (Ajiboye, Shonibare and Oyinloye, 2020). The phenolic compounds commonly found in sea cucumbers are gallic acid, P-coumaric acid, ferulic acid, cinnamic acid, catechin, routine, quercetin, and pyrogallol. The research results report that phenolic compounds are able to inhibit oxidation, mediate anti-inflammatory actions by blocking the MAPK signaling pathway, inhibit the synthesis of pro-inflammatory cytokines, especially nitric oxide synthase (iNOS), nitric acid (NO), TNF- α, IL-1β, and PGE2 (Hossain, Dave and Shahidi, 2022).

According to previous research, peptide supplements increase the body's antioxidant capacity by providing hydrogen atoms or electrons, which help eliminate free radical reactions, chelate with metal ions to form inert complexes, prevent ROS and free radical formation, and increase the activity of antioxidant enzymes (Q. Wang et al., 2021). A study reported that peptides present in sea cucumbers act as reducing agents capable of protecting cells from oxidative stress by eliciting cell signal responses such as mitogen-activated protein kinase (MAPK), phosphoinositide 3-kinase (PI3K) or Akt signaling pathways, and nuclear factor signaling. NFκ-B (Lu et al., 2021).

Apart from that, phytochemical compounds such as carotenoids in sea cucumbers also have strong antioxidant properties (David et al., 2023). The main carotenoids contained in sea cucumbers are astaxanthin and canthaxanthin (Senadheera, Dave and Shahidi, 2020). The characteristic chemical structure of carotenoids (conjugated C=C) shows antioxidant properties that are related to the scavenging of ROS, especially singlet oxygen (O_2) and peroxyl radicals (Hossain, Dave and Shahidi, 2022).

The antioxidant potential of polysaccharides in sea cucumbers from previous studies revealed that polysaccharides show strong reducing power and the ability to capture hydroxyl radicals, DPPH, and superoxide (Wargasetia et al., 2023). The ability of free radicals to extract anomeric hydrogen from polysaccharides may be the cause. In addition, this is due to its association with its structural features such as its monosaccharide composition and the content of its carboxyl and sulfate groups (Hossain, Dave and Shahidi,

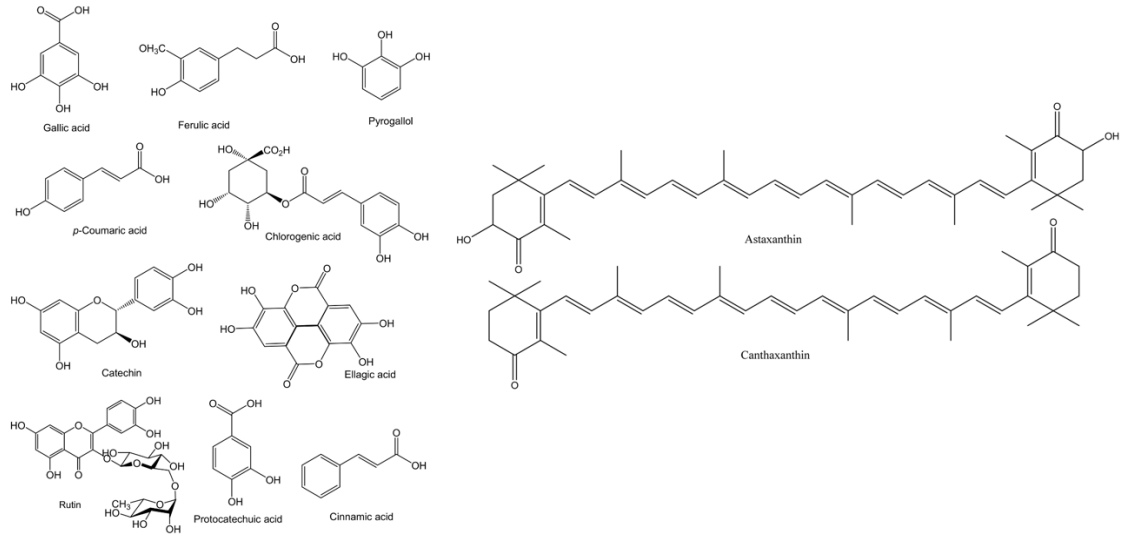

Fig. 4. Major phenolic compounds found in sea cucumbers (Hossain, Dave and Shahidi, 2020)

2022). This group is able to bind metal ions (Cu2+ and Fe2+) and is able to capture hydroxyl radicals (Hossain, Dave and Shahidi, 2022). In addition, because the sulfate group in sulfated polysaccharides is an electron-donating substituent in the polymerization process, the sulfate group can initiate superoxide radical scavenging activity (Hossain, Dave and Shahidi, 2022).

Oxidative stress is caused by an imbalance between the body's ability to capture free radicals and reactive oxygen species (ROS) and the formation of pro-oxidants (Darenskaya, Kolesnikova and Kolesnikov, 2021). In sports, oxidative stress occurs approximately one hour after exercise which is characterized by an increase in reactive oxygen species (ROS). (McKeegan et al., 2021). Nuclear factor E2 (NRF2)-mediated signaling pathway controls the inhibition of oxidative stress. NRF2 is an important transcription factor that controls the expression of several antioxidant enzymes, ultimately increasing the body's capacity to defend against free radicals (Q. Wang et al., 2021). Various diseases associated with oxidative stress, such as heart disease, neurological disease, cancer, diabetes mellitus, and uncontrolled inflammatory processes due to intense exercise can be prevented or treated with chemicals containing phenolic compounds (Senadheera, Dave and Shahidi, 2020). This compound is believed to have the capacity to scavenge free radicals and function as an antioxidant that can reduce oxidative stress, thus helping a person in the post-exercise recovery process (Mason et al., 2020; Rojano-Ortega, 2021). Phenolic compounds can inhibit enzymes that cause ROS to become highly oxidized and reduce the amount of ROS produced (Aatab et al., 2023).

The idea that sea cucumbers contain antioxidant properties and reduce oxidative stress is supported by a study conducted on male Sprague Dawley (SD) rats reporting that oral administration of sea cucumber extract intervention has the potential for high antioxidant activity (P. Wang et al., 2021). A study reported that sea cucumber hydroxylate extract (SCH), which mostly consists of peptides, was able to reduce oxidative stress and inflammation in mice (Wang et al., 2023). SCH supplements can increase GSH and SOD while reducing MDA. The results of this research also report that GSH and SOD act as antioxidants which can scavenge free radicals through activating the Akt/NRF2/NQO1 signaling pathway so that they are effective in reducing oxidative stress (Wang et al., 2023). Thus, the antioxidant effect of SCH is due to the presence of peptide compounds with large amounts of aromatic and hydrophobic amino acids through hydrogen bonds and hydrophobic interactions to disrupt the Keap1-Nrf2 interaction and modulate the Akt/NRF2 pathway, which plays an important role in its strong radical scavenging activity resulting in has the potential to fight oxidative stress.

This research is also strengthened by a laboratory study which reported that sea cucumber and tunicate extracts have potential antioxidant and anti-inflammatory activity (Carletti et al., 2022). This observation is supported by the high levels of polyphenols contained in sea cucumbers and tunicates. Polyphenolic compounds are able to provide a protective effect against reactive oxygen species in cells and reduce the detrimental effects of pro-inflammatory signals (Carletti et al., 2022). Furthermore, other studies reported that sea cucumber extract showed high antioxidant potential due to its phenolic content (Aatab et al., 2023). This extract functions as a hydrogen donor in stopping the oxidation process through free radical stabilization. Bioactive compounds such as phenolic acids (gallic acid, caffeic acid, pyrrolic acid, and vanillic acid) are able to ward off free radicals (Aatab et al., 2023). Therefore, these polyphenolic compounds contribute to antioxidant activity. The results of this research are strengthened by research which reports that sea cucumber extract is predicted to have anticancer activity from sea cucumber bioactive compounds as anti-inflammatory and antioxidant (Wargasetia et al., 2023). This active compound is able to ward off DPPH and NO radicals and has the potential to inhibit certain proteins that trigger oxidative stress (Wargasetia et al., 2023). Sea cucumber extract works by inhibiting the activity of the KEAP1 and iNOS proteins by blocking their interaction with the DLG NRF2 motif thereby inhibiting the occurrence of oxidative stress in cells. (Wargasetia et al., 2023).

Furthermore, EIMD and increased ROS will trigger inflammation and reach its peak 24-48 hours after exercise (Chang et al., 2021; Hung et al., 2021). The inflammatory response due to exercise triggers a decrease in muscle strength,

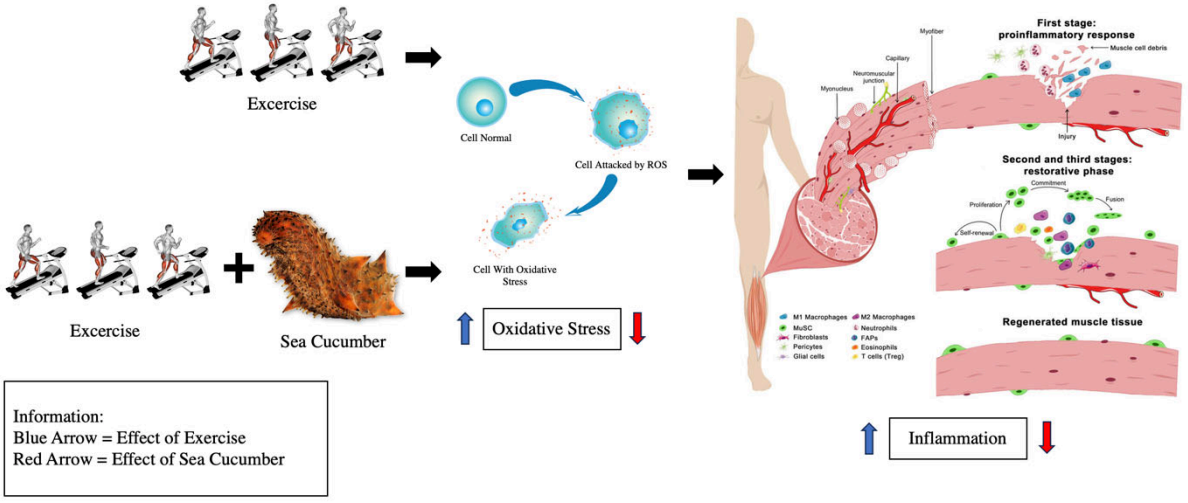

Fig. 6. Mechanism of Action of Sea Cucumbers to Reduce Oxidative Stress and Inflammation

decrease ROM, DOMS. (Ayubi, Kusnanik, Herawati, Muhammad, et al., 2023). In inflammatory situations, other myokines such as TNF-α and interleukin-10 IL-10 are also expressed (Porto et al., 2023; Volpe-Fix et al., 2023). TNF-α is one part of the pro-inflammatory cytokines that trigger muscle pain (Fernández-Lázaro et al., 2020; Ayubi et al., 2022; Nanavati et al., 2022). Related to this, sea cucumber SCP is also able to reduce pro-inflammatory cytokines such as TNF-α, IL-1β, IL-6 (P. Wang et al., 2021). SCP can inhibit TLR4 expression and NF-κB activation thereby reducing the release of pro-inflammatory cytokines (P. Wang et al., 2021). The results of this research were strengthened by research on mice which reported that sea cucumber extract was able to inhibit the lipoxygenase enzyme which causes inflammation (Ghaffari et al., 2019).

So, in short, the phenolic content contained in sea cucumbers has antioxidant properties that can reduce oxidative stress and anti-inflammatory properties that can reduce exercise pro-inflammatory cytokines. For more details regarding the benefits of sea cucumbers in reducing oxidative stress and inflammation, see Figure 6.

Conclusions

The phenolic content in sea cucumbers has strong antioxidant properties in reducing oxidative stress. Furthermore, the anti-inflammatory properties of sea cucumbers can reduce uncontrolled inflammation due to exercise. In this case, sea cucumbers work by reducing inflammation by suppressing the secretion of pro-inflammatory cytokines. Through this systematic review, we recommend that future research conduct clinical trials on the potential of sea cucumber on oxidative stress biomarkers and inflammatory biomarkers after exercise.

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Conflicts of Interest

The authors declare no conflict of interest

List of Abbreviations

ROS	Reactive Oxygen Species
EIMD	Exercise-Induced Muscle Damage
ROM	Range of Motion
DOMS	Delayed Onset Muscle Soreness
CK	Creatine Kinase
LDH	Lactate Dehydrogenase
Mb	Myoglobin
CRP	C-Reactive Protein
IL-1	Interleukin 1
IL-6	Interleukin 6
IL-10	Interleukin 10
IL-1β	Interleukin 1β
TNF-α	Tumor Necrosis Factor Alpha
NF kB	Nuclear Factor Kappa Beta
NSAIDs	Nonsteroidal Anti-Inflammatory Drugs
iNOS	Inducible Nitric Oxide Synthase
NO	Nitric Oxide
PGE2	Prostaglandin E2
SCP	Sea Cucumber Peptides
SCH	Sea Cucumber Hydrosylate
MDA	Malondialdehyde
SOD	Superoxide Dismutase
PC	Positive Control
MC	Model Control
ATP	Adenosine Triphosphate
SD	Sprague Dawley
BUN	Blood Urea Nitrogen
NH3	Hyperammonaemia
LG	Liver Glycogen
MG	muscle glycogen
NRF2	Nuclear Factor E2-Related Factor
AMPK	AMP-Activated Protein Kinase
GOT	Glutamic Oxalacetic Tansaminase
U-MA	Micro-albumin urine
AEs	Aqueous Extracts
DPPH	2,2-Diphenyl-1-Picrylhydrazyl
Cu2+	Copper(2+)
Fe2+	Ferro
O_2	Oxygen

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Потенціал впливу фітохімічних сполук морського огірка на зменшення оксидативного стресу та запалення, спричинених виконанням фізичних вправ: систематичний огляд

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 3 с., 1 табл., 6 рис., 43 джерела.

Мета дослідження. Метою цього дослідження є аналіз та висвітлення потенціалу впливу морського огірка на зменшення оксидативного стресу та запалення, спричинених фізичними вправами.

Матеріали та методи. Дослідження є різновидом систематичного огляду з використанням пошуку в різних наукометричних базах даних журналів, таких як Science Direct, Pubmed та Web of Science. Критеріями включення до даного дослідження були журнали, опубліковані за останні 5 років, в яких розглядалися такі питання, як морський огірок, оксидативний стрес, запалення та фізичні вправи. Крім того, критеріями виключення в цьому дослідженні були журнали, які не є авторитетними або не індексуються в Scopus і Web of Science. Загалом було виявлено 1038 статей з наукометричних баз даних Science Direct, Pubmed та Web of Science. Для даного систематичного огляду було відібрано та проаналізовано загалом 8 статей, які відповідали критеріям включення. Що стосується стандартних операцій, дане дослідження проводилося відповідно до оцінки «Переважні елементи звітності для систематичних оглядів і мета-аналізів» (PRISMA).

Результати. Результати даного систематичного оглядового дослідження свідчать, що високий вміст фенолів у морському огірку має антиоксидантні властивості, які можуть зменшити рівень оксидативного стресу. Крім того, протизапальні властивості морських огірків потенційно сприяють зниженню неконтрольованого запалення, спричиненого інтенсивними фізичними вправами.

Висновки. Вміст фенолів у морських огірках має сильні антиоксидантні властивості, зменшуючи рівень оксидативного стресу. Крім того, протизапальні властивості морських огірків можуть зменшити неконтрольоване запалення, викликане фізичними навантаженнями. В цьому випадку морські огірки володіють протизапальною дією, пригнічуючи секрецію прозапальних цитокінів. На основі цього систематичного огляду ми рекомендуємо в майбутніх дослідженнях провести клінічні випробування щодо потенціалу впливу морського огірка на біомаркери оксидативного стресу та запалення після виконання фізичних навантажень.

Ключові слова: морський огірок, оксидативний стрес, запалення, фізичні вправи.

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REVIEW ARTICLE

Potential of Polyphenolic Compounds in Rosella Flowers on Reducing Oxidative Stress and Inflammation After Exercise: A Systematic Review

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Abstract

Study purpose. This study aims to analyze and highlight the potential of rosella flowers in reducing oxidative stress and inflammation after physical activity.

Materials and methods. The study used a systematic review method by searching various journal databases such as Scopus, Web of Science, Pubmed and Embase. The inclusion criteria in this study were articles published in the last 5 years and articles discussing Rosella Flowers, Oxidative Stress, Free Radicals, Inflammation, and Exercise. The exclusion criteria in this research were articles published in disreputable journals. A total of 357 articles from the Scopus, Web of Science Pubmed and Embase databases were identified. A total of 8 articles that met the inclusion criteria were selected and analyzed for this systematic review. For standard operations, this study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) assessment.

Results. The results of this systematic review research report that the flavonoid content found in rosella flowers has anti-oxidant and anti-inflammatory properties which have the potential to reduce oxidative stress and uncontrolled inflammation caused by physical activity and intense exercise.

Conclusions. Rosella flowers show their ability as an anti-oxidative by donating hydrogen atoms to free radicals through phenolic compounds, thus breaking the cycle of ROS formation. The natural active ingredients in rosella flowers are able to reduce MDA and increase GSH which contributes to reducing oxidative stress and decreasing TNF-α which provides an anti-inflammatory effect in athletes after exercise.

Keywords: rosella flower, oxidative stress, free radicals, inflammation, exercise.

Introduction

Recently, most people have adopted a healthy lifestyle through regular exercise, thus preventing the onset of various diseases (diabetes, cancer, Alzheimer's, cardiovascular and dementia) as well as improving physical fitness and health. Regular exercise can also reduce peroxidants, increase antioxidant capacity and activate antioxidant enzymes, all of which help in protecting cells from the harmful effects of oxidative stress and stopping cell damage (Taherkhani, Suzuki & Castell, 2020; Daniela et al., 2022; Amiri et al., 2023). However, intense and irregular sports training actually causes athletes to experience inflammation, oxidative stress, muscle damage and injury, and chronic fatigue, which are associated with the toxic effects of free radicals. Increased oxidative stress can be assessed through

malondialdehyde (MDA) and advanced oxidation rate of protein products (AOPP), which are biomarkers of oxidative damage. Meanwhile, reducing oxidative stress can be seen from increasing levels of antioxidants, such as superoxide dismutase (SOD) and glutathione peroxidase (GXP) (Souissi et al., 2020). Oxidative stress is an imbalance between antioxidants and oxidant processes that causes molecular damage and disruption of redox signals and control. Excessive production of reactive oxygen species (ROS) and reactive nitrogen species (RNS) causes disruption of the redox balance, causing inflammatory effects (Kruk et al., 2022). Increases in inflammatory mediators, such as tumor necrosis factor-α (TNF-α), interleukin-6 (IL-6), NF-kB, and C-reactive protein (CRP), correlate with an imbalance in ROS production (Merrigan & Jones, 2021). This causes chronic inflammation, which then triggers oxidative stress and chronic inflammation (El Assar et al., 2022).

Oxidative stress occurs after exercise-induced muscle damage (EIMD) with increased reactive oxygen species (ROS) (Bindu, Mazumder & Bandyopadhyay, 2020). EIMD can cause pain or muscle loss during the first 12-72 hours after exercise (Ayubi et al., 2023). The inflammatory response due to EIMD triggers a decrease in muscle strength, decreased range of motion (ROM), delayed muscle soreness (DOMS), local swelling, and an increase in muscle proteins in the blood (creatine kinase (CK), lactate dehydrogenase (LDH), and myoglobin (Mb) (Jamurtas, 2018; Fern & Mielgo-ayuso, 2020). Researchers have focused on using pharmaceutical, nutritional, and physical methods to reduce the inflammatory response in muscle damage caused by eccentric exercise. Free radicals and ROS caused by oxidative stress during exercise can be stabilized using antioxidants found in plants. Antioxidant supplementation in research conducted by (Canals-Garzón et al., 2022) reported that antioxidant properties were able to reduce oxidative stress by attenuating the lipid peroxidation response and reducing malondialdehyde (MDA) directly. Excessive ROS production in the body can be protected and reduced through antioxidant enzyme systems such as superoxide dismutase (SOD) and catalase (CAT). Apart from that, antioxidants have also been proven to be able to ward off free radicals and prevent destructive effects by limiting ROS damage mechanisms by reducing oxidative stress and inflammation (Amiri et al., 2023).

Supplements containing high levels of phenolic compounds derived from plants, for example, polyphenols (PC) have antioxidant and anti-inflammatory properties that can reduce oxidative stress, thus helping athletes to recover after exercise (Mason et al., 2020; Rojano-Ortega, 2021). Polyphenols are a group of phytochemicals in plants that are classified into four main classes, namely stilbenes, lignin, phenolic acids and flavonoids (Zhang et al., 2022). There are several factors for the use of polyphenols in improving post-exercise recovery, namely signaling activity that increases endogenous antioxidant responses, protective effects on red blood cells, and improved blood vessel function (Rudrapal et al., 2022). The structural components in polyphenols function as RONS scavengers and their antioxidant activity also has an indirect effect (Rudrapal et al., 2022). This is proven by the presence of a phenolic group and 2-3 double bonds as well as a 4-keto group in ring C which is able to capture free radicals and chelate metals so that this compound can significantly fight and protect against the effects of oxidative stress (Platzer et al., 2021). Most studies report that reducing inflammation and oxidative stress can be achieved by consuming polyphenols for at least 3 consecutive days before and after vigorous exercise sessions to improve muscle injury repair (Kruk et al., 2022; O'Connor, Mündel and Barnes, 2022).

One natural product that can be used, with potential anti-inflammatory and antioxidant effects, is the rosella flower. Hibiscus sabdariffa L. or known as Rosella contains vitamins, minerals and bioactive components, such as polyphenols (anthocyanins, flavonoids, phenolic acids, tannins), polysaccharides, pectins, non-phenolic organic acids, carotenoids, caffeic acid, chlorogenic acid, acid ascorbate, and quercetin, which makes it a powerful antioxidant (Singh et al., 2021). One of the polyphenols which are classified as flavonoids which have strong antioxidant properties is anthocyanin (Jin et al., 2022). This compound is a powerful free radical scavenger with inhibiting glycation and scavenging activity against DPPH and superoxide anions thereby increasing antioxidant activity or reducing ROS to detoxify oxidative damage (Jin et al., 2022). Roselle can also be further studied as a pharmacological treatment to reduce risk factors for cardiovascular disease because it has been proven to have antihyperlipidemic, antihyperglycemic, antioxidant, anti-inflammatory, antihypertensive, and antifibrosis properties (Ratna et al., 2018; Jamrozik, Borymska & Kaczmarczyk-Żebrowska, 2022; Khongrum et al., 2022; Sapian et al., 2023). Therefore, we want to relate and discuss in depth the potential use of Rosella in reducing oxidative stress and inflammation after physical activity through a systematic review.

This study aims to analyze and highlight the potential of Rosella in reducing oxidative stress and inflammation after physical activity.

Materials and methods

Study Design

This research uses a systematic review method by searching various journal databases such as Scopus, Web of Science, and Pubmed. It is considered a premier platform worldwide as it brings together publications that have scientific impact and relevance.

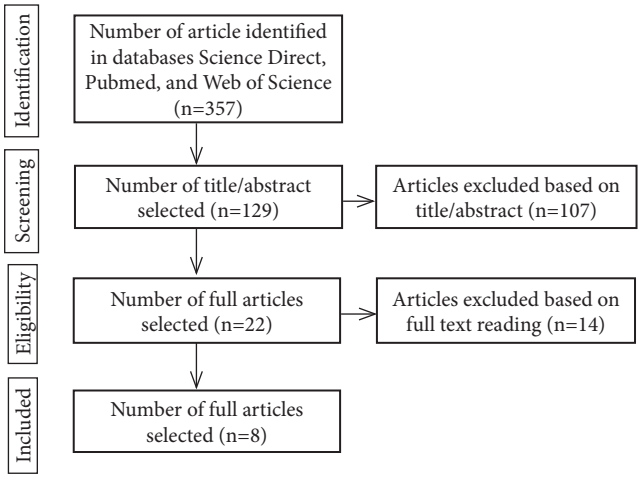


Fig 1. PRISMA flowchart of the article selection process

Eligibility criteria

The inclusion criteria in this study were articles published in the last 5 years and articles discussing Rosella, Oxidative Stress, Free Radicals, and physical exercise. The exclusion criteria in this study were articles published in disreputable journals.

Procedure

Titles, abstracts and full texts of articles were screened then verified and stored in Mendeley software. In the first stage, 357 articles from the Science Direct, Web of Science, and Pubmed databases were identified. Next, in the second stage, 129 articles were screened based on the suitability of the title and abstract. In the third stage, 22 articles were ordered for further processing. At this stage, we filter based on the overall suitability of the article. Then in the final stage 8 articles were selected that met the inclusion criteria and analyzed for this systematic observation. For standard operations, this study follows the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) assessment.

Results

Table 1. Results of a review of the effects of rosella on oxidative stress and free radicals

Author	Sample Characteristics	Study Design	Intervention	Results
Khongrum et al. (2022)	Rosella flowers were collected and dried at 50ºC for 24 hours. Then it is ground and extracted to obtain a thick extract. Rosella extract was given to 43 adults suffering from dyslipidemia and grouped based on exclusion criteria into 2 groups, namely the RP jelly drink group and the placebo group.	Experimental	Subjects in the treatment group were given 300 mL rosella supplements once a day for 8 weeks. Then, subjects were asked to do physical activities such as moderate exercise, vigorous activity, walking, and sitting. Then the serum lipid profile, inflammation parameters, and oxidative stress status were analyzed.	Rosella supplementation given to subjects showed a significant reduction in LDL-C and TG. This can be proven by decreasing tumor necrosis factor-α (TNF-α) and malondialdehyde (MDA), as well as increasing glutathione (GSH), resulting in reduced inflammation and improved oxidative stress.
Singh et al. (2021)	Rosella samples were dried and made into powder. Rosella powder is extracted with water, methanol and ethanol and the mixture is centrifuged, filtered, evaporated to obtain a dry extract.	Laboratory experiments	Rosella samples were made into powder by drying. Then it is extracted using several solvents. The concentrated extract is filtered and evaporated to obtain a dry extract. Sample extracts were tested for total phenolic content, flavonoid content, DPPH radical scavenger test, and antioxidant activity test.	Rosella extract is reported to contain many polyphenolic and flavonoid compounds which contribute to antioxidant activity.
Ratna et al. (2018)	25 Male rats weighing 150-180 g were grouped into 5 groups, namely negative control rat group (standard feed without rosella extract), positive group (hot feed without rosella extract), treatment group 1 rosella extract 200 mg.kg/BW (R1), treatment group 2 rosella extract 300 mg.kg/BW (R2), and treatment group 3 rosella extract 400 mg.kg/BW (R3).	Experimental	Subjects were given rosella supplements orally for 4 weeks according to the dosage. Next, the subject's internal organs were taken for further analysis such as measuring serum CML, measuring IL-6 and amyloid.	Giving rosella supplements to subjects can increase serum CML levels, reduce IL-6 levels significantly, and reduce amyloid levels significantly. So this supplement has the potential to reduce oxidative damage and increase antioxidant performance.
Ujianti et al. (2023)	Rosella extract samples were given to subjects orally, where 30 male Sprague-Dawley rats were grouped into 6 groups and given the following treatment: (1) normal control group, (2) vitamin B12 restricted diet group without rosella extract, and (3) group limited diet vitamin B12 + rosella extract.	Experimental	Subjects were given rosella extract supplementation at a dose of 400 mg/kg/weight/day for 8 and 16 weeks. After that, the subjects' organs and blood samples were taken for histological and biochemical analysis.	The results of phytochemical analysis show that rosella extract contains bioactive compounds such as flavonoids, saponins, tannins, triterpenoids and quinones. Rosella extract supplementation can significantly reduce levels of pro-inflammatory cytokines and increase anti-inflammatory cytokines, reduce levels of TNF-α and IL-6, and increase levels of IL-10 and Nuclear-erythroid-2 Associated Factor 2 (NRF2). So it can be concluded that rosella extract is able to reduce inflammation and reduce oxidative stress.

Table 1. Continued

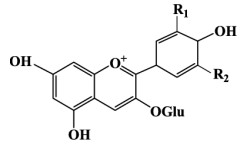
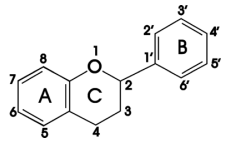
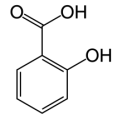
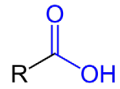
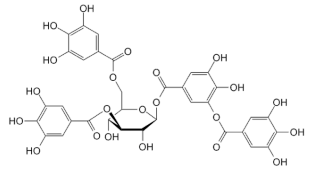
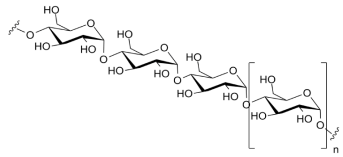
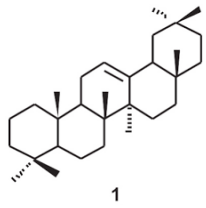
Author	Sample Characteristics	Study Design	Intervention	Results
Marhuenda et al. (2020)	84 sedentary and healthy subjects were given rosella extract supplements and a placebo for 84 days. Subjects were divided into 2 groups, namely the placebo group and the rosella extract group.	Experimental	Samples of rosella extract and placebo were given orally to subjects according to the dosage for 84 days. Then the subjects were asked to do physical exercise and blood samples were taken for analysis processes such as measuring LDL, HDL, triglycerides and total cholesterol.	It was reported that rosella extract caused a decrease in LDL and cholesterol after consumption by the subjects. Rosella extract as a source of bioactive compounds has a high polyphenol content so it has the potential for antioxidant and anti-inflammatory activity. In addition, this compound has been proven to be able to reduce oxidative stress and inhibit the increase in triglycerides and inflammatory adipokines.
Santoso et al., (2019)	Rosella extract was given orally to subjects at a dose of 500 mg/kg BW 5 times a week for 11 weeks. Subjects were 25 male Wistar rats weighing 200-250 g, divided into 5 groups, namely: control group (C), control + rosella extract (C+HSL), excessive training (OT), excessive training + rosella extract (OT+HSL), and aerobic (A).	Experimental	Rosella extract supplementation at a dose of 500 mg/kg was given to subjects for 11 weeks according to group division. Subjects did physical exercise and then samples of the subject's organs were taken to measure IL-6 and TNF-α levels.	The results of this study report that rosella extract can reduce levels of TNF-α and IL-6 significantly. This is due to the presence of bioactive compounds such as quercetin and anthocyanins which have the potential to act as antioxidants and anti-inflammatory.
Anel, Subapriya & Singh (2019)	Rosella petals are washed, dried, and ground into powder. Then it was made into a drink supplement which was given to 30 athletes aged 15-19 years (20 boys and 10 girls). Subjects were divided into 2 groups, namely the experimental group and the placebo group.	Experimental	Rosella supplementation was given to athletes orally at a dose of 240 mL before and after physical exercise for 90 days. Fitness parameters (vertical jumps, sit ups, long jumps) and blood samples were taken to analyze antioxidant levels.	Rosella extract supplementation can increase the subject's blood hemoglobin by significantly reducing serum Malondialdehyde (MDA) levels. So this extract has the potential to reduce oxidative stress and has antioxidant activity.
Mohamed et al. (2022)	Rosella flowers are dried and ground into powder, then extracted. Rosella extract was administered orally to 15 male Sprague-Dawley rats.	Experimental	Rosella extract supplementation was given to subjects orally. Then the extract was tested for antioxidant activity (lipid peroxidation, GSH, SOD, catalase activity), phenolic content, spectrophotometric analysis, and antidiabetic activity test.	Rosella extract contains high levels of polyphenolic compounds. This compound has strong potential as an antioxidant that can capture free radicals (DPPH), inhibit nitric oxide (NO) radicals, and increase iron ion-reducing power (FRAP). This extract can also increase SOD levels and reduce MDA levels, thereby reducing oxidative stress.

Discussion

The main research objective of this systematic review is to analyze and highlight the potential of rosella in reducing oxidative stress and inflammation after physical exercise. Rosella flower with the Latin name "Hibiscus sabdariffa L." is a plant that is found in tropical countries such as Brazil, the Philippines, Hawaii, the Caribbean, and Australia, as well as places such as India, Malaysia, Thailand, Indonesia, and China. Rosella belongs to the Malvaceae family and more than 300 species of rosella have been identified. The morphology of this plant is that it has a maximum height of 2.5 m, the stem is dark red and cylindrical in shape, the leaves are deeply lobed, 3-5 alternate with a length of 8-15 cm, and the edges of the leaves have teeth. The flowers are 8-12 cm in diameter, found singly in the terminals or axils of the leaves, white to pale yellow with a dark red spot at the base of each petal, and have sturdy fleshy petals at the base, 1-2 cm wide, expanding to 3-3.5 cm , fleshy and bright red when the fruit is ripe (Figure 1) (Riaz & Chopra, 2018; Jamrozik, Borymska & Kaczmarczyk-Żebrowska, 2022; Wang et al., 2022; Sapian et al., 2023).

Rosella flower petals have the potential to treat various diseases such as cardiovascular disease, diabetes, obesity, coughs, hypercholesterolemia, hypertension, kidney and skin diseases, and digestive disorders. Rosella flower petals are known for their therapeutic potential which is rich in protein (5.5-9.14%), carbohydrates (7.4-12.3%), and fat (0.47-1.32%) (Singh et al., 2021; Mohamed et al., 2022). Apart from being rich in dietary fiber, rosella is known to contain various bioactive compounds such as polyphenols (flavonoids, phenolic acids, anthocyanins, and tannins), pectin, polysaccharides, carotenoids, and non-phenolic organic acids, which are responsible for various biological and pharmacological functions such as anti-hyperglycemic, anti-hyperlipidemia, anti-hypertension, antioxidant, anti-inflammatory, anti-fibrosis, antimicrobial, anticarcinogenic, hepatoprotective and antidiabetic, which can be seen in full

Table 2. Active chemical compounds in Hibiscus sabdariffa

Chemical Groups	Active Compounds	Structure
Anthocyanins	delphinidin-3-sambubioside cyanidin-3-sambubioside delphinidin-3-glycoside cyanidin-3-glycoside	
Flavonoids	quercetin, hibiscetin (hibiscetin-3-glucoside), sabdaritrin, gossypitrin, and other gossypetin glycosides, luteolin, rutin	
Phenolic acids	chlorogenic acid, protocatechuic acid, caffeic acid, gallic acid	
Non-phenolic organic acids	hibiscus acid, hydroxy citric acid, malic acid, ascorbic acid, oxalic acid, succinic acid, tartaric acid, arachidic acid, citric acid, pelargonic acid	
Tannins	no specific name indicated	
Polysaccharides (Sugars)	galactose, galacturonic acid, rhamnose, arabinose, glucose, mannose, xylose, pectins	
Triterpenoids	α-amyrin, lupeol	
Others	calcium, magnesium, iron, trace elements, vitamins, and polyphenols	-

in Table 2 and Figure 3 (Frank et al., 2012; Jamrozik, Borymska & Kaczmarczyk-Żebrowska, 2022; Sapian et al., 2023)

It has been found that the phytochemical components in rosella have strong antioxidant qualities which have the ability to prevent the negative effects of oxidative stress. Antioxidants are responsible for scavenging free radicals thereby preventing oxidation. Antioxidant activity can be attributed to the presence of phenolic acids and flavonoids (Hossain, Dave & Shahidi, 2022). Based on research by (Sapian et al., 2023) reported that rosella extract given to obese mice was able to reduce oxidative stress by increasing superoxide dismutase (SOD) enzyme activity and glutathione (GSH) concentrations, as well as downregulating NOX2 and 8-isoprostane gene expression. This is because phenolic acid, anthocyanin and flavonoid compounds can capture free

Fig. 2. Roselle plant (Riaz & Chopra, 2018; Sapian et al., 2023)

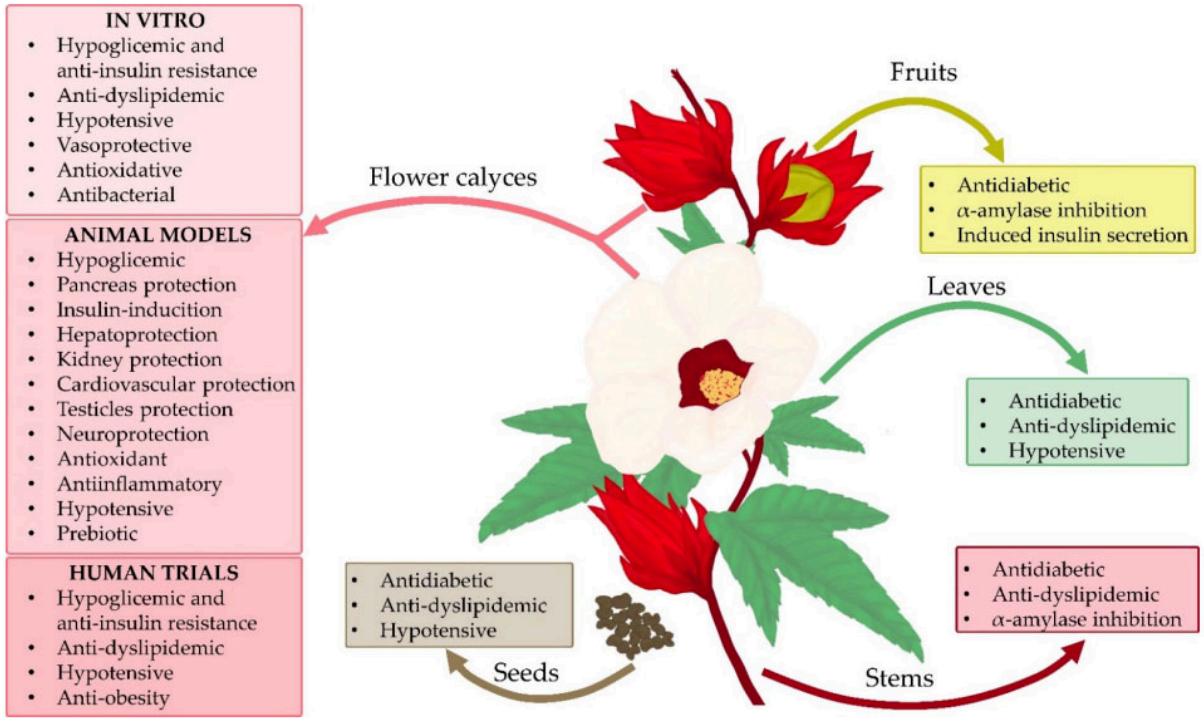


Fig. 3. Beneficial effects of different parts of roselle (Jamrozik, Borymska and Kaczmarczyk-Żebrowska, 2022)

radicals such as reactive nitrogen species (RNS) and ROS, thereby inhibiting oxidative stress.

Hibiscus acid, hydroxycitric acid, malic acid, ascorbic acid, oxalic acid, succinic acid, tartaric acid, arachidic acid, and citric acid are the most significant organic acids in roselle. This compound can reduce oxidation and encourage the production of the anti-inflammatory cytokine IL10, which in turn inhibits pro-inflammatory cytokines such as IL-6 and TNF-α. Therefore, roselle has strong antioxidant properties that can reduce cardiovascular inflammation and have cardioprotective effects (Sapian et al., 2023). In addition, polyphenols are also responsible for the antioxidant effects of Rosella. Delphinidin-3-sambubioside and cyanidin-3-sambubioside are the two most significant anthocyanins found in roselle. The most significant flavonoids that have been extracted from roselle are luteolin, gossypitrin and various glycosides gossypetin, sabdaritrin, quercetin, and hibiscetin (hibiscetin-3-glucoside). Along with many other phytochemicals, there are phenolic acids such as caffeic acid, protocatechuic acid, and chlorogenic acid. Glucose, mannose, xylose, rhamnose, arabinose, galactose and galacturonic acid make up the majority of sugars in roselle flower petals. Some authors also imply that in the petals there are triterpenoids such as α-amyrin and lupeol (Riaz & Chopra, 2018; Jamrozik, Borymska & Kaczmarczyk-Żebrowska, 2022).

Polyphenols have a benzene ring with one or more hydroxyl groups (-H2O) attached to it. According to their chemical structure, phenolic compounds are divided into five main classes, namely phenolic acids, flavonoids, stilbenes, lignin and condensed tannins. The class of polyphenols that accounts for 80% of all polyphenol chemicals are flavonoids. The framework of this class of polyphenols consists of two aromatic rings (rings A and B) which are connected by three carbon atoms to form a heterocyclic ring C which has an oxygen atom. Flavonoids are divided into six subclasses, namely flavones, isoflavones, flavonols, flavanols, flavanones, and anthocyanidins which can be seen in Figure 3. Polyphenols act in preventing and reducing the impact of oxidative stress originating from the presence of phenolic groups, 2-3 double bonds, and 4 groups. -keto on the C ring, which allows free radical capture and metal chelation (Kruk et al., 2022). A study reported that phenolic compounds are able to inhibit oxidation, mediate anti-inflammatory actions by blocking the MAPK signaling pathway, inhibit the synthesis of pro-inflammatory cytokines, especially nitric oxide synthase (iNOS), nitric acid (NO), TNF-α, interleukin-1β (IL-1β), and prostaglandin E2 (PGE2) (Hossain, Dave & Shahidi, 2022).

Regular physical activity practice has been proven to be able to maintain health by increasing immunity, reducing the risk of various diseases such as diabetes, osteoporosis, cancer, Alzheimer's, cardiovascular disease, and so on. However, intense and irregular exercise actually causes inflammation, oxidative stress, muscle damage and injury, which are associated with the toxic effects of free radicals (FR) (Souissi et al., 2020; Taherkhani, Suzuki & Castell, 2020; Daniela et al., 2022). Reactive oxygen species (ROS) are produced in large amounts during exercise. This species plays a significant physiological function in exercise adaptation. However, these ROS will increase in large amounts if physical exercise is carried out for a long period of time and excessively, causing an imbalance in antioxidant defenses, which ultimately results in oxidative stress (Martins et al., 2020). Oxidative stress occurs due to an imbalance between the production of free radicals in the body and the body's capacity to detoxify free radicals by neutralizing

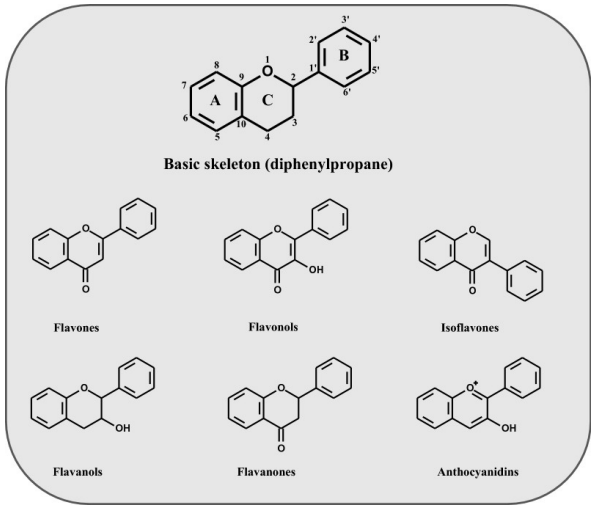


Fig. 4. Chemical structure of flavonoids and their main subclasses

their damaging effects through antioxidant mechanisms. Malondialdehyde (MDA), a major marker of lipid oxidation, is one of the end products of the oxidation process that can be used to identify this phenomenon. Numerous studies report that oxidative stress can cause a number of problems for athletes, including fatigue, inflammation, and muscle injury (Hadi et al., 2017).

Microtrauma/muscle injury can be healed adaptively through an inflammatory process. However, continuous intense exercise causes chronic inflammation. This inflammatory process can interfere with an athlete's recovery by developing muscle pain during physical exercise. Therefore, an important strategy for post-exercise recovery is needed, where muscle fibers produce and release pro-inflammatory myokines such as IL-6 when physically active. In inflammatory situations, other myokines such as TNF-α and IL-10 are also expressed (Santoso et al., 2019; Porto et al., 2023; Volpe-Fix et al., 2023). TNF-α is one part of the pro-inflammatory cytokines that trigger muscle pain (Fernández-Lázaro et al., 2020; Ayubi et al., 2022; Nanavati et al., 2022). TNF-α produced by heart cells is responsible for the inflammatory response to stress (Santoso et al., 2019). Nuclear factor E2 (NRF2)-mediated signaling pathway controls the inhibition of oxidative stress. NRF2 is an important transcription factor that controls the expression of several antioxidant enzymes, ultimately increasing the body's capacity to defend against free radicals (Wang et al., 2021).

Various diseases related to oxidative stress, such as heart disease, neurological disease, cancer, diabetes mellitus, and uncontrolled inflammatory processes due to intense exercise can be prevented or treated with chemicals containing phenolic compounds. This compound is believed to have the capacity to scavenge free radicals and function as an antioxidant and anti-inflammatory which can reduce oxidative stress, thus helping athletes in the post-exercise recovery process (Mason et al., 2020; Rojano-Ortega, 2021). Phenolic compounds can inhibit enzymes that cause ROS to become highly oxidized and reduce the amount of ROS produced (Aatab et al., 2023). In addition, the production of IL-6 and TNF-α can be suppressed through the use of quecetin and anthocyanin compounds. IL-6 production can be inhibited by quercetin through the regulatory effect of p38-mitogen-activated protein kinase (p38-MAPK). The expression of TNF-α can also be suppressed by this compound through reducing NF-kβ gene expression and decreasing Iκβα and Iκββ phosphorylation so that quercetin can reduce NF-κβ activation. Anthocyanin compounds can also inhibit the production of nitric oxide, rostaglandin E2, TNF-α, and IL-6. Anthocyanins have been reported to reduce the formation of reactive oxygen species, which in turn reduces MAPK activation and inflammatory cytokine production. Anthocyanins reduce the synthesis of proinflammatory mediators such as IL-6 and TNF-α by blocking the translocation of NF-κβ from the cytosol to the nucleus and preventing the phosphorylation of Iκβ (Santoso et al., 2019). One natural product that contains this bioactive is rosella. Rosella has antioxidant and anti-inflammatory properties and can be an intervention strategy in reducing oxidative stress and controlling uncontrolled inflammatory processes due to intense exercise.

The idea that rosella contains antioxidant properties and reduces oxidative stress is supported by a study by (Khongrum et al., 2022) who reported that rosella extract contains many polyphenols, anthocyanins, quercetin and gallic acid which contribute to lowering lipids and inhibiting LDL-C oxidation through antioxidant activity. Oxidative stress can be inhibited by using polyphenolic compounds. In this study, the natural active ingredients in rosella supplementation were able to reduce maloddialdehyde (MDA) and increase glutathione (GSH) which contributed to reducing oxidative stress and reducing tumor necrosis factor-α (TNF-α) which provided an anti-inflammatory effect. This research is also strengthened by a laboratory study which reports that rosella extract has potential for antioxidant activity. This observation is supported by the high levels of polyphenols and flavonoids contained in rosella. The main polyphenolic compounds from this extract are delphinidin 3-O-sambubioside chloride and cyanidin 3-O-sambubioside chloride which are classified as anthocyanin compounds. In addition, antioxidant activity can be seen from the significant increase in DPPH values through scavenging free radicals thereby inhibiting oxidative stress (Singh et al., 2021).

Furthermore, the results of other research show that rosella extract has strong antioxidant properties due to the presence of active compounds such as flavonoids, alkaloids, anthocyanins, bsitosterol, and ascorbic acid. Delphinidin 3-sambubioside (DP3-Sam), an anthocyanin compound, has a higher antioxidant effect than other antioxidants because it is able to inhibit the expression of inflammatory mediators. The compounds contained in rosella extract are able to reduce iNOS, IL-6, NO, MCP-1, and TNF-α by downregulating the NF-kB and MEK1/2 – ERK1/2 signal pathways and by inhibiting free radicals. Antiocyanins are also able to reduce Aβ levels through scavenging free radicals and reducing ROS, thereby detoxifying oxidative damage and strengthening antioxidant action (Ratna et al., 2018). Research by (Ujianti et al., 2023) reported that rosella extract can inhibit the formation of homocysteine which causes oxidative stress. This is caused by rosella extract which contains several bioactive compounds such as flavonoids, quinones, tannins, triterpenoids and saponins. This compound is believed to have antioxidant and anti-inflammatory activity by capturing ROS and free radicals, reducing reactive O_2, and preventing the formation of free radicals. Rosella extract

supplementation is responsible for increasing antioxidant defense and reducing lipid peroxidation against oxidative stress through the NRF2 signaling pathway. This extract can reduce pro-inflammatory cytokines such as TNF-α and IL-6 by inhibiting the development of NAFLD and increasing anti-inflammatory cytokines such as IL-10.

Additionally, research studies by (Marhuenda et al., 2020) revealed that rosella extract contains polyphenolic compounds, namely quercetin-3-O-β-D-glucuronide and aglycone, which are responsible for inhibiting the increase in triglycerides, inflammatory adipokines, and free radicals that cause oxidative stress. Quercetin can inhibit TNF-α gene expression by modulating NF-κβ. So this extract has the potential for antioxidant and anti-inflammatory activity. This research is strengthened by (Santoso et al., 2019) who reported that rosella extract has antioxidant and anti-inflammatory properties because it contains polyphenolic compounds such as quercetin and anthocyanin. This compound can reduce pro-inflammatory mediators by inhibiting IL-6 production and reducing TNF-α expression by reducing NF-κβ activation. Anthocyanins also play a role in reducing ROS production thereby reducing the production of inflammatory cytokines. So it was concluded that rosella extract supplementation had a protective effect against chronic inflammation.

Other research by (Anel, Subapriya and Singh, 2019) strengthens reports that rosella extract supplements contain phytochemicals such as flavonoids, tannins, alkaloids, saponins and anthraquinones which have the potential to act as antioxidants. This antioxidant property can reduce serum MDA levels so that it can reduce oxidative stress in athletes after physical exercise. In addition, research by (Mohamed et al., 2022) shows that rosella extract supplementation has high antioxidant and antidiabetic potential due to its high polyphenol content. This antioxidant property plays a role in inhibiting oxidative stress damage through the donation of hydrogen atoms by phenolic compounds to free radicals thereby breaking the cycle of ROS formation. The increase in GSH levels which acts as a defense against free radicals after administration of rosella extract shows its anti-oxidative ability. In addition, rosella extract is able to increase SOD activity, thereby showing anti-oxidative ability and reducing oxidative stress. With increasing levels of SOD, GSH, and catalase activity, MDA levels decrease due to the antioxidant properties of this rosella extract.

So, the polyphenol content (phenolic acids, flavonoids and anthocyanins) contained in rosella has antioxidant and anti-inflammatory properties which have the potential to reduce oxidative stress and inflammation due to intense exercise. Furthermore, for more details regarding the benefits of rosella in reducing oxidative stress and inflammation, see Figure 5.

Conclusions

The polydenol compounds such as flavonoids, phenolic acids and anthocyanins found in rosella have anti-oxidant properties which can reduce oxidative stress. In this case, rosella extract shows its ability as an anti-oxidative through donating hydrogen atoms by phenolic compounds to free radicals thereby breaking the cycle of ROS formation. The natural active ingredients in rosella flowers are able to reduce MDA and increase GSH which contributes to reducing oxidative stress and reducing TNF-α which provides an anti-inflammatory effect in athletes after physical exercise. The compounds contained in rosella extract are able to reduce iNOS, IL-6, NO, MCP-1, and TNF-α by downregulating the NF-kB and MEK1/2 – ERK1/2 signal pathways and by inhibiting free radicals. Antiocyanins are also able to reduce Aβ levels through scavenging free radicals and reducing ROS, thereby detoxifying oxidative damage and strengthening antioxidant work. We recommend that rosella can be used in individuals to reduce oxidative stress and inflammation caused by physical activity and intense exercise.

Acknowledgments

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Conflicts of Interest

The authors declare no conflict of interest.

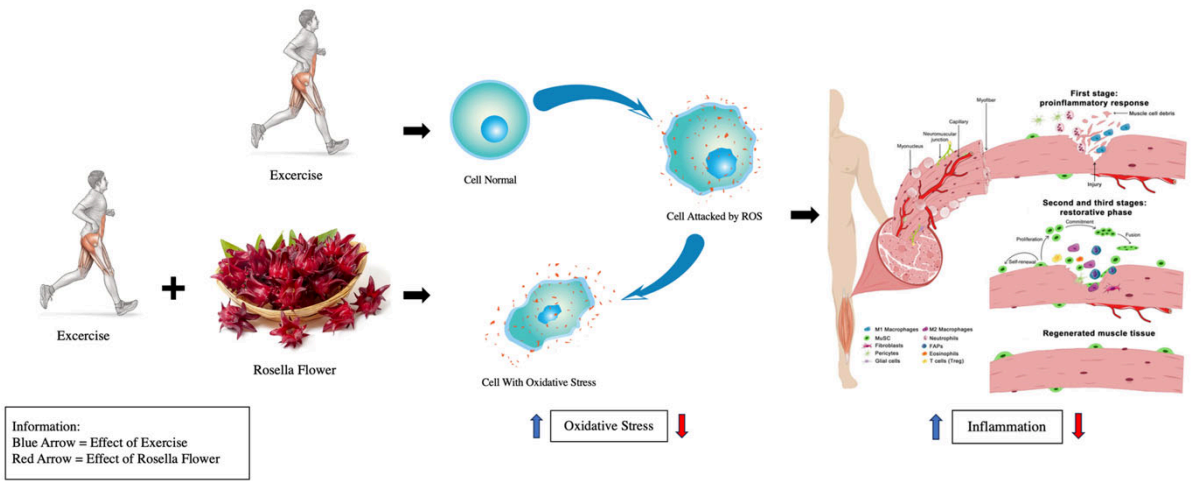

Fig. 5. Mechanism of Action of Rosella Flowers to Reduce Oxidative Stress and Inflammation

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Потенціал впливу поліфенольних сполук квітів розелли на зменшення оксидативного стресу та запалення після проведення фізичних вправ: систематичний огляд

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 11 с., 2 табл., 5 рис., 42 джерела.

Мета дослідження. Метою даного дослідження є аналіз та визначення потенціалу впливу квіток розелли на зменшення оксидативного стресу та запалення після фізичної активності.

Матеріали та методи. У дослідженні використовувався метод систематичного огляду шляхом пошуку в різних наукометричних базах даних журналів, таких як Scopus, Web of Science, Pubmed та Embase. Критеріями включення до даного дослідження були статті, опубліковані за останні 5 років, а також статті, в яких розглядалися такі питання, як квіти розелли, оксидативний стрес, вільні радикали, запалення та фізичні вправи. Критеріями виключення в дослідженні були статті, опубліковані в недоброчесних журналах. Загалом було знайдено 357 статей з науковометричних баз даних Scopus, Web of Science Pubmed та Embase. Для даного систематичного огляду було відібрано та проаналізовано загалом 8 статей, які відповідали критеріям включення. Що стосується стандартних операцій, дане дослідження проводилося відповідно до оцінки «Переважні елементи звітності для систематичних оглядів і мета-аналізів» (PRISMA).

Результати. Результати даного систематичного оглядового дослідження свідчать, що вміст флавоноїдів у квітках розелли має антиоксидантні та протизапальні властивості, які потенційно сприяють зниженню оксидативного стресу та неконтрольованого запалення, спричиненого фізичною активністю та інтенсивним тренуванням.

Висновки. Квіти розелли володіють антиоксидантною дією, оскільки через фенольні сполуки передають атоми водню вільним радикалам, розриваючи таким чином цикл утворення АФК. Природні активні компоненти квітів розелли мають здатність зменшувати рівень МДА та підвищувати вміст GSH (глутатіону), що сприяє зменшенню оксидативного стресу та зниженню рівня TNF-α, який забезпечує протизапальний ефект у спортсменів після виконання фізичних навантажень.

Ключові слова: квітка розелли, оксидативний стрес, вільні радикали, запалення, фізичні вправи.

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