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ORIGINAL SCIENTIFIC PAPER

Effect of a 12-Week High Intensity Interval Training on Serum Brain Derived Neurotrophic Factor of Obese Undergraduates

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Abstract

The study investigated the effect of a 12-week High Intensity Interval Training (HIIT) on Serum Brain Derived Neurotrophic Factor (BDNF) among obese undergraduates of the University of Benin. The pretest-posttest randomized experimental design was employed for the study. The study involved a population of one hundred and twenty obese undergraduates, with a sample of twenty-four selected using simple random sampling. The participants' anthropometric profiles were analyzed descriptively using mean and standard deviation, and the hypothesis was tested using analysis of covariance (ANCOVA) with statistical significance set at a p-value of <0.05. The Bonferroni post-hoc test was conducted to pinpoint the source of the differences between the groups. The results showed a significantly higher increase in Serum BDNF levels (2.07 ± 1.9 vs. 2.38 ± 2.1) in the experimental group. This suggests that the HIIT protocol had a notable impact on the serum BDNF concentration of the obese undergraduates. Therefore, HIIT may serve as an effective intervention for elevating BDNF levels and potentially enhancing brain health. The study recommends that policymakers in Nigeria and other sub-Saharan African nations should prioritize addressing obesity due to its potential cognitive complications.

Keywords: *BDNF, Obese undergraduates and HIIT*

Introduction

Obesity is a multifaceted condition that is influenced by genetics, control of the energy balance, and significant environmental factors. It presents serious negative effects on the health of the general population. The prevalence of obesity and overweight has been steadily rising worldwide, and the pace of increase in African nations like Nigeria is comparable to that seen in affluent nations (Chukwuonye, et al., 2022; Templin et al., 2019). Obesity is associated with psychosocial disorder, and one of which is a decline in academic achievement and cognitive function (Taras & Potts-Datema, 2005; Cournout et al., 2006). Obesity-related research on cognitive function has centered on Brain Derived Neurotrophic Factor (BDNF), a neurotrophin associated with memory and appetite control. Secretion of BDNF through increased expression of BDNF mRNA in the hypothalamus is influenced by physical exercises. Since exercise triggers an upsurge in BDNF mRNA gene expression within the hippocampus, the protein has been regarded as a possible component of the biological processes that form the basis for how aerobic exercise influences the hippocampal memory system. (Rossanti et al., 2015).

Exercise is also known to improve mood and cognitive abilities, although, the physiological mechanism underlying this benefit is yet unknown. Previous studies conducted by Eimuhi et al., (2021) revealed that the use of an acute exercise of HIIT initiated an increase in the serum BDNF concentration of obese undergraduates, however, with no significant level. Furthermore, inconsistency in findings has existed regarding increase, decrease or no change in the levels of serum BDNF following HIIT protocol (Airin et al, 2014; Alberto et al., 2018; Jimenez-Maldonado et al., 2018). Therefore, the aim of this research is to investigate the impact of a 12-week HIIT protocol as a chronic exercise intervention on the serum BDNF levels in obese undergraduates from the University of Benin.

Hypothesis

A hypothesis was formulated to guide the study.

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- There will be no significant difference in the Serum BDNF concentration of obese undergraduates following a 12-week HIIT programme in the experimental and control groups.

Methodology

The pretest-posttest randomized experimental design was employed. A subset of twenty-four (24) individuals was selected from a larger pool of one hundred and twenty (120) obese undergraduate students at the University of Benin. These participants were members of the University of Benin's Obesity Fitness Group (OFG) and regularly participated in exercise sessions. Twenty % of the population was represented by the sample that was chosen. Participants without any form of visible disability met the study's inclusion criteria. Participants who fell below the rigorous BMI cut-off of 30 kg/m2 were excluded from the study. Using a simple random sample method, the candidates were chosen. Subsequently, the participants were randomly divided into the experimental and control groups. This division involved numbering the 24 selected obese participants and then assigning them to either the control or experimental group, resulting in twelve individuals in each group. Ethical approval for the study was obtained from the Ethics Board of the University of Benin, Benin-City, Nigeria with approval number EC/UNIBEN/28/2024.

Anthropometric Measurements

The study's goals were explained to the participants, and they became acquainted with the anthropometric tests and tools. Prior to commencing the High-Intensity Interval Training (HIIT) program, initial data collection involved conducting pre-test assessments of anthropometric parameters. The same protocols were used to conduct post-test measurements immediately after the intervention period had ended. In particular, a calibrated stadiometer was used to measure each participant's height as they stood barefoot The study utilized an Omron Body Composition Monitor (Omron Healthcare, 2019) to measure participants' body mass and percentage of body fat, with participants wearing snug attire during the measurements. In this research, we assessed internal consistency reliability. To ensure the appropriateness of both the HIIT protocol and the measuring instrument, a preliminary study was conducted involving eight (8) independent subjects, with four (4) individuals in each group. The data collected using the multilevel modeling method were then subjected to Interclass Correlation Coefficient (ICC) analysis, yielding a high reliability with a Correlation Coefficient of 0.75. This result validated the suitability of employing the instrument and protocol for the present study.

Biochemical Analysis

The blood sample collection process followed the guidelines presented by WHO (2010). Two blood samples were taken: once prior to training and once just after the HIIT intervention. A medical laboratory expert took blood samples from the antecubital veins of the volunteers who had not eaten or drunk all night as they sat in a chair for 15 minutes. To allow blood to coagulate, blood samples were kept at room temperature for an hour. The expressed serums from the blood sample were centrifuged and stored at -80°C for further analyses. BDNF levels were assessed using an ELISA kit (enzyme-linked immunosorbent assay) (Eastbiopharm, Hangzhou Co. Ltd, China).

Training Protocol

The HIIT protocol consisted of: 1) a 10-minute warm-up session that incorporated activities like jogging, stretching, and running at an initial intensity of 50% of the maximum heart rate, gradually increasing to 85% during the session; and 2) a 20-minute strength training routine targeting major upper and lower body muscles.

The 12-week HIIT protocol was applied to the Experimental group. The HIIT intervention required a 10-minute warm-up that includes stretching, jogging, and running for 5 minutes at 50% to 85% of one's maximum heart rate (training began with 50% intensity). Next, the participants took part in a 20-minute session focused on strengthening their major upper and lower body muscles. This session involved a variety of exercises such as windmills, burpees, sit-ups, heel raises, side jumps, alternate lateral tilting, and alternate leg-arm kicking, which they executed at intensity levels varying from 50% to 80% of their one-repetition maximum. They completed three sets of 10 repetitions for each exercise, with a 1-minute rest interval between sets and a 2-minute break between exercises. This training regimen was carried out over a duration of 12 weeks. The end of each training session was followed by a mild 10-minute walk to cool down. The research carried out by Machado et al. (2017) and Nazari et al. (2016) confirmed the effectiveness of the HIIT protocol. In contrast to subjecting the participants in the control 10 min warm up with a consistent pace + 20 min strength training with 50% of 1RM.

Statistical Analysis

The data analysis was conducted with the IBM version 20 of the Statistical Package for Social Sciences (SPSS). Descriptive statistics, including mean and standard deviation, were employed to characterize the sample's anthropometric and BDNF profiles. Inferential statistics involving analysis of covariance (ANCOVA) was employed to test the hypothesis. The Bonferroni post-hoc test was conducted to pinpoint the source of the differences between the groups. The significance level, denoted by the alpha level, was set at 0.05.

Table 1: Descriptive Statistics Showing Physical, Anthropometric Characteristics and Serum BDNF concentration of the Subjects (n=24)

Variable	Group		
	Measuring	Control (n=12)	Experimental (n=12)
Age (yrs)	Pre-training	26.3 ± 9.4	27.5 ± 4.1
Height (cm)	Pre-training	1.69 ± 0.1	1.74 ± 0.1
Weight (kg)	Pre-training	90.2 ± 8.4	92.9 ± 8.2
	Post-training (Chronic)	90.1 ± 8.3	90.7 ± 8.6
BMI (kg/m^2)	Pre-training	31.9 ± 4.0	30.5 ± 4.2
	Post-training (Chronic)	30.4 ± 3.9	30.2 ± 4.1
Body Fat (%)	Pre-training	39.0 ± 8.2	38.1 ± 10.1
	Post-training (Chronic)	38.1 ± 9.4	39.2 ±10.9
BDNF (ng/ml)	Pre-training	2.61 ± 2.8	2.07 ± 1.9
	Post-training (Chronic)	2.63 ± 2.9	2.38 ± 2.1

* BMI – Body Mass Index, * BDNF – Brain Derived Neurotrophic Factor, Values expressed as Mean ± SD

Results

Table one displays the average values and standard deviations for the physical and anthropometric traits (age, height, body mass index, body fat percentage) of individuals in both the experimental and control groups. The table also illustrate a rise in Serum BDNF levels when comparing the pretest and posttest assessments in both the experimental and control groups. In the experimental group, there was an increase in Serum BDNF, with a mean and standard deviation of 2.07 ± 1.9 and 2.38 ± 2.1 at the posttest assessment. Similarly, the control group also showed a slight increase in Serum BDNF, with a mean and standard deviation of 2.61 ± 2.8 and 2.63 ± 2.9 at the posttest assessment when compared to the pretest assessment. To determine whether these differences are statistically significant or not, it became necessary to test the hypothesis.

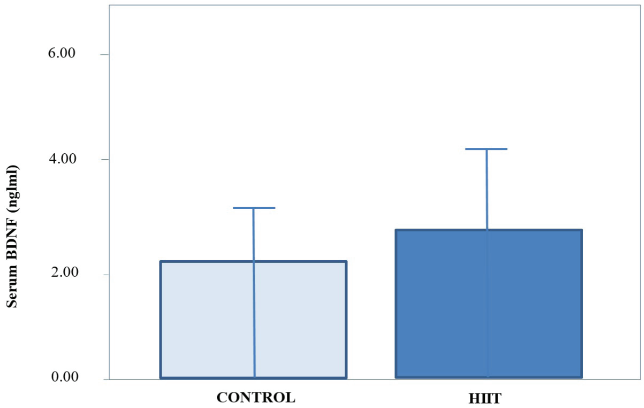

FIGURE 1: Serum BDNF level in the control (n=12) and experimental group (n=12). Data are expressed as the mean±SD; p<0.05.

Table two shows F (1,21) = 5.162, ($p < 0.0005$) < $\alpha = 0.05$. Hence, there was a significant difference in post-BDNF between the experimental and control group while adjusting for pre-BDNF. This means that the null hypothesis was rejected. The partial Eta Squared (0.92) when compared with Cohen's guidelines shows that the effect of this difference is large on the Obese Undergraduates. Furthermore, 92% variance in BDNF was accounted for by 12-Week High Intensity Interval Training.

The adjusted mean difference (1.371 ± 1.25) between the experimental and control group is presented in Table three. There was a significant difference (($p < 0.0005$) < $\alpha = 0.05$) between the adjusted means of the experimental and control group while adjusting for the covariate 'pre-BDNF'. Thus, the HIIT protocol (experiment) presented a more significant effect than the control group (without HIIT protocol).

Table 2: ANCOVA test on the difference in the effect of the control and experimental Treatment Measure

Dependent Variable: post						
Variable	Sum of squares	df	Mean Square	F	Sig.	Partial eta squared
Corrected Model	2018.232a	2	2018.232	2.131	<0.001	0.916
Intercept	835.478	1	835.478	1.813	<0.001	0.692
Pre-BDNF	7.288	1	7.288	.824	<0.462	0.017
Treatment SSbetween	2024.855	1	2024.855	5.162	<0.001	0.915
Error SSwithin	1492.372	21	11.267			
Total	19492.000	24				
Corrected Total	2211.232	23				

a. R Squared = .916 (Adjusted R Squared = .912)

Table 3: Pairwise comparisons of the adjusted means of the effect of the control and experimental treatment measure

Dependent Variable: post						
(I) treatment	(J) treatment	Mean Difference (I-J)	Std. Error	Sig.b	95% Confidence Interval for Differenceb	
					Lower Bound	Upper Bound
1.00	2.00	1.371	1.250	<0.001	1.125	3.749
2.00	1.00	-1.371	1.250	<0.001	-3.749	-1.125

Based on estimated marginal means *. The mean difference is significant at the 0.05 level. b. Adjustment for multiple comparisons: Bonferroni.

Discussion

In this study, we examined variations in BDNF levels among obese undergraduate students after a 12-week HIIT program. The results of our investigation demonstrated a noteworthy rise in serum BDNF levels among the obese students after undergoing the HIIT intervention when compared with the control group without HIIT intervention. This discovery aligns with the findings of Nazari et al. (2016) and Saucedo Marquez et al. (2015), both of which also observed increased serum BDNF concentrations in their participants. The 12-week HIIT exercise may have promoted the release of BDNF from a number of tissues, which could have contributed to the increase in BDNF levels. Increased gene expression and the activation of transcriptional pathways may also be responsible for this. According to Wrann et al. (2013), the biochemical pathways that lead to an increase in BDNF concentration in the brain may be started by the musculoskeletal contractions that occur during HIIT programs. The level of physical activity during an intervention period may have a significant impact on how much BDNF is present. Exercise types and intensities can alter BDNF responses as well.

In contrast to this report, the study by Kim (2016) found that serum BDNF concentration had significantly decreased. This divergence in results is not surprising given that Mehrjardi (2017) analyzed a different sample of athletes and found that athletes frequently engage in high-intensity workouts that might cause tissue damage and necessitate on-going healing. Similarly, among the same population, earlier research shown that routine exercise decreased basal BDNF among sports people (Nofuji et al., 2014). BDNF plays a role in the healing process after injuries (Kim, 2016). Another possible explanation for this discrepancy in results is that 90% of blood BDNF proteins are stored in platelets, with platelet activation facilitating their release during the clotting process (Kim, 2016). Exercise causes mechanical and functional stress, which damages the muscles and causes nerve damage (Clarkson & Hubal, 2002). The inconsistencies may have been caused by timing and other blood sample techniques.

The results of ANCOVA of the hypothesis tested showed that the adjusted mean of the experimental group was significantly higher from that of the control group. A variance of 92% in BDNF concentration was accounted for the HIIT protocol. Thus, while both the control and experimental groups in our study exhibited increased serum BDNF levels, it's noteworthy that the magnitude of this increase was more pronounced in individuals who underwent the HIIT intervention. This suggests that the HIIT program could potentially serve as an effective means to promote brain health. The outcome of the independent sample t-test led to the rejection of the null hypothesis, which posited that there would be no significant alteration in the serum BDNF levels of the obese undergraduates after completing the 12-week HIIT program. This implies that the administered HIIT program indeed had a substantial impact on the participants' serum BDNF levels.

Conclusion

In light of the results obtained in this research, it was concluded that HIIT protocol initiated a significantly higher increase in the serum BDNF concentration of the obese undergraduates when compared with the control group not exposed to HIIT protocol.

Recommendation

Based on the findings, policymakers in Nigeria and other sub-Saharan African nations should pay more attention to obesity because as it may pose severe cognitive complications. Obese students should be made aware of the many advantages of the HIIT program on overall health and wellbeing. Also, coaches and personal trainers should attend seminars or courses where they may learn more about how to implement HIIT training into their workouts to enhance serum BDNF levels.

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NARRATIVE REVIEW

Shoulder girdle injuries in volleyball players: structure, symptoms, cause and prevention. A narrative review

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Abstract

Shoulder joint injuries are a major concern in volleyball, particularly among elite athletes who undergo rigorous training sessions and frequently participate in competitions. Given that volleyball is a polystructured sport that requires volleyball players to constantly change the amplitude of movement in the shoulder joint, frequent injuries such as subacromial impact syndrome, compression of the suprascapular nerve, bursitis and tendinitis of the rotator cuff occur. In order to prevent injuries, prevention programs are increasingly introduced today. Consequently, the aim of this research was to describe the structure and prevention of shoulder girdle injuries in volleyball players. Prevention programs developed by researchers have been shown to be effective in reducing the prevalence of shoulder injuries. Prevention programs include adequate warming up, strengthening and stretching of the muscles of the shoulder girdle, as well as correct execution of technical elements. The development and implementation of individualized prevention and rehabilitation programs can significantly contribute to reducing the risk of injuries and prolonging the sports career of volleyball players.

Keywords: *shoulder joint injuries, prevention, rehabilitation, volleyball*

Introduction

William Morgan could not find any sport similar to today's volleyball. By aligning his unique methods of training and recreation, he created a game he called "Mintonette" (Rustamovich, 2024). Mintonette is the original name of today's Olympic team sport – volleyball (G'ayratovich, 2022). Volleyball belongs to semi-structured sports with unpredictable dynamics of both cyclic and acyclic types of movements (Nešić et al., 2020; Yue & Hong, 2023). Like most sports, volleyball physically strains and activates the entire human musculature through various forms of movement (Reitmayer, 2017). This sport is based on natural forms of movement that constantly alternate, such as running, jumping, landing, sprinting, digging, hitting the ball, and blocking (Cosmin et al., 2016; Tsoukos et al., 2019). In addition to natural forms of movement, volleyball requires players to perform short high-intensity actions followed by low-intensity activities (Gabbett et al., 2007; Kilic et al., 2017; Majstorović et al., 2020). Matches generally last between 60 and 100 minutes, during which more than 250 actions are performed with jumps accounting for about 50-60%, defense with landings about 15%, and rapid changes of direction 27-33% (García-de-Alcaraz et al., 2020; Mori et al., 2022). Indeed, players on the court perform a series of different motor activities involving movements with and without the ball to achieve specific goals during the game (Mroczek et al., 2014). While performing basic and specific movements, some muscle groups are more, and some less strained compared to others (Cuñado-González et al., 2019). Numerous studies suggest that the strains create asymmetries in various sports disciplines that negatively affect the human body (Fort-Vanmeerhaeghe et al., 2016; Parpa & Michaelides, 2022). Asymmetry appears in many sports, including volleyball (Hadzic et

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al., 2014; Kozinc & Šarabon, 2020). Cuckova & Suss (2014) in their study found that the dominant side of female volleyball players' bodies is under greater strain, leading to body asymmetry. Such conclusions are explained by the shortening or excessive tension of certain muscle groups during the execution of motor movements and technical elements specific to volleyball. Indeed, due to the tension and overstrain of certain muscle groups, injuries in volleyball often occur (Wang & Cochrane, 2001). Injuries in volleyball occur due to jumping, landing, or grounding but nowadays increasingly from hitting and blocking the ball (Chojęta et al., 2020). Generally, sports injuries are divided into acute and overuse injuries (Višnjevac et al., 2009; Višnjevac et al., 2020). Overuse injuries are somewhat more common than acute injuries in volleyball (Cieśla et al., 2014; de Azevedo Sodré Silva et al., 2023). Various factors contribute to the occurrence of injuries, the most common being improper technique, fatigue, and overtraining (Zetou et al., 2006). Also, professional volleyball players are at greater risk of injuries compared to amateur players due to more intense training, competition schedules, and loads (Azuma et al., 2019; Eerkes, 2012). The most common injuries in volleyball are ankle injuries, followed by knee injuries including anterior cruciate ligament rupture, hand injuries, lumbar spine injuries, and shoulder joint injuries (Eerkes, 2012; Migliorini et al., 2019).

Accordingly, the goal of this research was to summarize the scientific evidence and describe in detail the structure of the most common shoulder girdle injuries in volleyball players, as well as the prevention and prevention program of shoulder girdle injuries, in order to prevent injury and thereby improve the health and prolong the sports career of volleyball players in the future.

Methods

For the collection, classification, and analysis of the targeted research, a descriptive method and theoretical analysis were used, while the material was gathered through internet databases and search engines: Google Scholar, Pub Med, Web of Science, and ResearchGate. The key terms used during the search included: shoulder joint injuries, prevention, rehabilitation, and volleyball. Only the studies relevant to the purpose of this research were considered. The search was limited to studies conducted on volleyball players who sustained shoulder joint injuries. Studies that were excluded from the analysis did not meet the criteria of having an adequate sample size, or the results were not adequately presented for further analysis.

Anatomy of the Shoulder Joint

The shoulder joint, also known as the glenohumeral joint, is an extremely mobile joint in the human body. The shoulder muscles have a wide range of functions, including movements such as lifting, lowering, rotating, and extending the arm (Bakhsh & Nicandri, 2018). The central bony structure of the shoulder is the scapula, which serves as the attachment point for all these muscles. On the surface of the scapula is the glenoid cavity, which along with the glenoid ligaments and muscle tendons, provides stability to the shoulder joint (Cowan et al., 2018). Additionally, there are other muscles that make up the shoulder girdle, such as the pectoralis major, pectoralis minor, deltoideus, trapezius, and serratus anterior. These muscles play an important role in supporting the shoulder joint and enabling various movements of the arms and shoulders. Furthermore, there are several joints that connect the pectoral girdle to the rest of the body, such as the sternoclavicular, coracoclavicular, and acromioclavicular joints (Card & Lowe, 2018). The scapula is a key bone located on the back and has numerous muscle attachments. The glenoid cavity on the scapula allows for smooth articulation with the head of the humerus. This is important for the stability of the shoulder joint and enables us to perform various arm movements. Additionally, the coracoclavicular and acromioclavicular joints contribute to the stability of the shoulder girdle (Holt et al., 1990). Embryologically, the upper extremities develop during fetal development through the process of cell condensation that differentiates into bones and cartilage. Muscle tissue begins to form around the seventh week of development. This process involves the migration of mesenchymal cells to the extremities and their differentiation into muscle fibers (Warmbrunn et al., 2018). In terms of vascularization, the upper extremity receives its blood supply from the subclavian artery, which further branches into the axillary artery. These arteries supply the shoulder muscles and ensure adequate blood circulation in this area (de la Garza et al., 1992). The nervous system plays a crucial role in innervating the shoulder muscles. Various nerves, such as the subscapular nerve, suprascapular nerve, axillary nerve, and others, innervate different muscle groups in the shoulder girdle, enabling them to perform their functions (Okwumabua et al., 2018). The rotator cuff muscles, including the supraspinatus, infraspinatus, teres minor, and subscapularis, are key structures for the stability of the shoulder joint. These muscles enable various arm and shoulder movements, such as lifting, lowering, and rotation. Additionally, muscles such as the trapezius, deltoideus, and others contribute to the mobility of the shoulder joint and allow us to perform everyday activities (Precerutti et al., 2010).

Common Shoulder Joint Injuries in Volleyball

Volleyball is considered a safe sport compared to other contact sports such as handball, football, and basketball (Challoumas et al., 2017; Engebretsen et al., 2013; Vaandering et al., 2023). However, volleyball players can be at risk due to tasks specific to volleyball. Generally speaking, the prevalence of shoulder joint injuries varies depending on the sports discipline (Cibulas et al., 2019; Nadler et al., 2004). Among athletes, shoulder injuries are frequently reported, which can result not only in pain and emotional difficulties but also in temporary or permanent cessation of a sports career (Wilk et al., 2020). The shoulder joint is naturally mobile but less stable, making it vulnerable to injuries under the pressure characteristic of volleyball (Seminati & Minetti, 2013; Tibowe et al., 2004). Volleyball-specific techniques such as spiking, blocking, and serving place significant stress on the shoulder girdle (Hadžić et al., 2022). In recent years, the rate of overuse shoulder injuries among elite volleyball players has increased from 16% to 47% (Eerkes, 2012; Ünver et al., 2020). Numerous studies indicate that outside hitters have a higher prevalence of shoulder injuries (Miranda et al., 2015; Young et al., 2023). These results are expected because they are the main attackers.

Subacromial Impingement Syndrome

The most common shoulder joint injury in volleyball is subacromial impingement syndrome (Erekes, 2012). The factor that contributes to the occurrence of this injury is the compression of one of the rotator cuff tendons (Longo et al., 2020). The rotator cuff consists of four muscles: subscapularis, supraspinatus, infraspinatus, and teres minor (Llopis et al., 2021). These four muscles stabilize the head of the humerus in the concave body of the shoulder joint (Seminati & Minetti, 2013). If one of the structures of the shoulder joint becomes entrapped, normal circulation in that area is impeded, leading to inflammation and swelling (Badıl Güloğlu, 2021). Due to swelling and inflammation, the rotator cuff thickens, making it difficult for the supraspinatus tendon to pass through the subacromial space (Seminati & Minetti, 2013). The cause of the injury is repetitive overhead arm movements such as spiking and serving (Rohit, 2010). Shoulder pain occurs, especially when raising the arm above shoulder and head level (Shah et al., 2014). Pain increases particularly during internal rotation (Sanati et al., 2022). This injury is often observed in attacking players and servers because they abduct the glenohumeral joint to about 150º during serves and spikes (Shah et al., 2014). Rehabilitation treatments include rest, ice therapy, physical therapy, strengthening the rotator cuff, and possibly corticosteroid injections (Karaca, 2016; Yavuz et al., 2014).

Suprascapular Nerve Compression

Following jumper's knee, one of the most common injuries among volleyball players is suprascapular nerve compression (Kezunović & Laković, 2010). This injury is more dominant among spikers (Mazza et al., 2021). The predominant symptom is pain in the lateral part of the dorsolateral shoulder area, which worsens during arm movements and activities above shoulder and head level (Bozzi et al., 2020). Suprascapular nerve injury occurs in the dominant arm (Kezunović & Laković, 2010). If the injury worsens, pain can manifest along the posterior part of the arm (Dotterweich et al., 2023). Pain can also become constant, accompanied by shoulder muscle weakness and fatigue (Habib et al., 2022). Muscle atrophy can be observed, especially in female volleyball players (Kezunović & Laković, 2010). The cause of this injury can be overuse and repetitive stress on the rotator cuff tendons (Kezunović & Laković, 2010). Suprascapular nerve compression in volleyball players can be treated in several ways (Strauss et al., 2020). One method is non-surgical treatment, which is applied to patients with nerve dysfunction but without muscle atrophy (Leider et al., 2021). The first step in non-surgical treatment is to avoid the activities that caused the injury (John et al., 2020). The second step involves physical therapies focused on strengthening the rotator cuff, deltoid, and spinatus muscles (Strauss et al., 2020). If there is no improvement after three to four months of non-surgical treatment, surgical decompression of the suprascapular nerve is undertaken (Brzoska et al., 2023). Additionally, if muscle atrophy is evident and there is severe pain that cannot be controlled with medication, surgical decompression of the suprascapular nerve is performed (Strauss et al., 2020).

Bursitis Injuries

Bursae synoviales or synovial bursae are smaller or larger structures located around certain joints (Halata, 2001). The function of bursae is to reduce friction between muscles and their tendons and the hard surfaces they rest on (Colas et al., 2004). The shoulder joint has eight bursae, of which the most important is the subacromial bursa (Skazalski et al., 2021). The subacromial bursa is located between the coracoacromial ligament, acromion, and deltoid muscle on one side and the joint capsule with the coracohumeral ligament and rotator cuff tendons on the other side (Colas et al., 2004). Bursitis occurs if the rhomboid and trapezius muscles do not stabilize the scapula during movements, leading to the elevation of the humeral head, which reduces the subacromial space (Skazalski et al., 2021). Clinical signs of bursitis include shoulder pain, reduced range of motion, especially above shoulder level, and weakness of surrounding muscle groups. Local signs of bursitis may include warmth and redness in the shoulder area. Rehabilitation is usually conservative. The primary goal is to relieve the shoulder joint, i.e., rest with the application of NSAID therapy (Khan et al., 2001). This is followed by a focus on physical therapy, which is primarily based on stretching and strengthening the rotator cuff muscles to achieve shoulder joint stabilization (Biundo et al., 2001).

Tendinitis and Rotator Cuff Tear

The most important functional structure of the shoulder joint is the rotator cuff (Ninković, 2020). Rotator cuff injuries are very common, not only among athletes but also among non-athletes (Ninković et al., 2014). During normal daily activities, approximately 140 to 200 N are transmitted through these tendons (Cicak, 2003). For volleyball players, the maximum load that a healthy rotator cuff tendon can transmit ranges from 600 to 800 N (Cicak, 2003). The exact diagnosis of a rotator cuff injury is determined through clinical examination, analysis of radiographic images, and magnetic resonance imaging (Wieser et al., 2019). Rotator cuff tendinitis in volleyball players results from overuse and constant repetitive stress (Čičak et al., 2015). Symptoms of rotator cuff tendinitis include shoulder pain accompanied by weakness in the shoulder joint muscles (Wieser et al., 2019). Rehabilitation treatment consists of rest, i.e., relieving the shoulder joint, and physical therapy (Menshova et al., 2021).

Rotator cuff tear, in most cases, represents a combination of untreated rotator cuff tendinitis and poor tendon nutrition, but it can also result from high-intensity force (Wieser et al., 2019). Treatment of a rotator cuff tear involves arthroscopic surgery followed by a rehabilitation period of three to six months with physical therapy (Menshova et al., 2021; Wieser et al., 2019).

Prevention of Shoulder Girdle Injuries

Since sports injuries can have a negative impact primarily on the continuation of a sports career, they can also result in high costs for society due to interventions based on exercises to prevent or reduce injuries (Cools et al., 2021; Gouttebarge et al., 2017). Maintaining normal kinetic function of the shoulder complex is one of the most challenging tasks in sports medicine (Emery & Pasanen, 2019). Identifying risk factors for shoulder injuries is essential for developing prevention strategies (Abernethy & Bleakley, 2007). The risk factor for musculoskeletal injuries in volleyball is more frequently reported in male volleyball players than female volleyball players (Kilic et al., 2017). The injury prevention model proposed by van Mechelen is the basis for assessing the development of prevention programs (Verhagen & van Mechelen, 2010). The model indicates that sports injury prevention begins with determining the extent of the injury, followed by identifying risk factors for injury in that sports discipline. This is followed by the development and validation of injury prevention strategies (Blauwet et al., 2019; van Mechelen, 1997). This model is still used in designing injury prevention.

The Oslo Sports Trauma Research Center has developed a shoulder injury prevention program. The shoulder injury prevention program increased internal rotation strength of the glenohumeral joint, external rotation strength, and scapular muscle strength (Kilic et al., 2017). The program consisted of warm-up exercises that reduced the prevalence of shoulder problems by 28% (Andersson, 2017). Warm-up before training and matches induces several phenomena related to the muscle-tendon system (Bishop, 2003). In the area of active muscles, muscle contractions increase circulation, leading to an increase in temperature in that area (Fradkin et al., 2010; McCrary et al., 2015). Increasing the temperature promotes the reduction of muscle tension and increases the viscoelastic properties of muscles (Safran et al., 1988). Thus, warming up achieves a range of physiological processes that increase muscle tolerance to the stresses and forces to which they are exposed (McCrary et al., 2015). In addition to the Oslo Sports Trauma Research Center, Fradkin et al. (2006) conducted a study to examine the extent to which warm-up actually affects injury prevention. The results confirmed that performing proper warm-up before training and matches reduces the risk of injury. Additionally, the combination of active and passive exercises reduces shoulder joint injuries (Huxel Bliven & Anderson, 2013). The first step in injury prevention through exercises begins with static exercises (Yu et al., 2015). They are desirable because in these exercises, the muscle does not perform movement and does not change its length but only changes the muscle tone (Yu et al., 2015). In static exercises, there is no load on the rotator cuff, but the muscles are strengthened. Of course, in addition to static exercises, injury prevention also includes unloading exercises that increase the range of motion while simultaneously strengthening the muscles (Abdulla et al., 2015). In active exercises, results are visible because active movement affects deeper structures (Escamilla et al., 2009). These exercises include muscle strengthening exercises with gravitational force, proprioception exercises, and exercises with elastic bands (Della Tommasina et al., 2023). Stretching exercises are also very important in injury prevention because stretching creates space between joint bodies while stretching muscles and tendons (Weerapong et al., 2004).

Based on existing scientific and practical knowledge, it is stated that systematic strengthening of shoulder muscles is crucial, especially for volleyball players, as a preventive measure against shoulder injuries (Abdulla et al., 2015; Swart & Olivier, 2021). Finally, although strong internal rotators are important for optimal volleyball performance, equally strong external rotators are necessary to maintain shoulder joint health in volleyball.

Shoulder Injury Prevention Program

The issue of shoulder injuries in the sports population emphasizes the need for a prevention strategy and effective rehabilitation programs. Therefore, there is a need for a global approach that includes shoulder injury prevention.

The shoulder injury prevention cycle consists of four steps (Van Mechelen et al., 1992). The first step is identifying the problem, followed by examining the injury mechanism (Van Mechelen et al., 1992). The third and fourth steps, which are also the most significant, involve introducing a prevention program and examining its effectiveness (Van Mechelen et al., 1992). Since the first and second steps have already been described in previous chapters, the focus will now be on the third and fourth steps. In the third step, preventive measures such as exercise or stretching programs are introduced, but preventive measures also include changing volleyball game rules, introducing protective equipment, and adapting the quality of sports equipment (Bahr, 2016). After introducing the prevention program, the effectiveness of the introduced prevention program is examined.

The most frequently asked question is whether preventive programs reduce the rate of shoulder injuries. In the scientific literature, opinions are divided. Andresson et al. (2017) demonstrated through research that preventive programs reduce the rate of shoulder injuries. Sommervold & Østerås (2017) did not find effects of the prevention program on shoulder injuries. They attributed these results to the players not adhering to the preventive program. Today, there is increasing evidence of possible risk factors for shoulder pain in the younger population of athletes. Many studies indicate that injury prevention programs have greater significance for the younger population (Asker et al., 2018; Cools et al., 2021). Of course, there may not be a possibility to predict an injury, but there is a possibility to prevent it. When programming a prevention program, it is necessary to involve multiple experts. Adherence to the exercise program increases by engaging the head coach, assistant coach, strength and conditioning coach, medical team, and parents (Cools et al., 2021).

Conclusion

Volleyball, as a popular sport with a huge number of participants, is unfortunately subject to injuries like many other sports. One of the frequent injuries is the shoulder girdle injury, which can keep the participant off the volleyball court for a short or long period of time. In sports in general, especially where players are exposed to constant repetitive high-intensity movements, this injury is a serious problem. The most common shoulder girdle injuries in volleyball players are subacromial impingement syndrome, compression of the suprascapular nerve, bursitis and rotator cuff tendinitis directly related to the specific biomechanical demands of volleyball. Understanding the anatomical and functional complexity of the shoulder joint is the first step to developing the most effective rehabilitation and prevention programs. There are many risk factors that contribute to the occurrence and worsening of injuries. So far, the most effective prevention programs against shoulder girdle injuries have been programs that include exercises to strengthen and stretch the muscles of the shoulder girdle, as well as proper warm-up before training and matches and proper execution of technical elements.

This scientific paper contributes to the already existing knowledge about the structure, symptoms and rehabilitation of shoulder girdle injuries in volleyball, but also provides guidelines for the practical application of new knowledge regarding injury prevention. The priority of future research should be the development of individual prevention programs for the specificity of sports injuries in order to preserve and improve the health of athletes.

Authors contributions

In this research, Ivana Delibašić conceived and designed the study, as well as wrote the first draft. Slavka Durlevic and Ina Markovic participated in writing the complete scientific paper, while Marija Durlevic contributed to the technical editing of the entire paper. All authors approved the final version submitted for publication.

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ORIGINAL SCIENTIFIC PAPER

Beyond Games: Unspoken Challenges of Pre-Service Physical Education Teachers – A Pilot Study

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Abstract

Studies on teacher preparation highlight the importance of practical experiences such as internships in adequately preparing pre-service teachers for the demands of the profession. However, there has been a lack of focus on the specific difficulties encountered by pre-service physical education (PE) teachers during internships. This study utilized qualitative methods to examine the specific obstacles encountered by eight pre-service physical education teachers while completing their internships at private secondary schools in the northern region of the Philippines. Through thematic analysis of weekly reflective journals, four main themes were identified: personal well-being and emotional strain, classroom management and student interactions, instructional practices and pedagogical challenges, and school environment and institutional factors. The results emphasize the importance of integrating well-being strategies into PE teacher education programs, improving PE-specific classroom management training, and promoting stronger partnerships between universities and schools to offer consistent support, resources, and practical experiences for future teachers navigating the complexities of the PE teaching environment. These findings contribute to a deeper understanding of the experiences of pre-service PE teachers and provide practical suggestions for enhancing teacher preparation and support systems.

Keywords: *physical education, pre-service teachers, teaching internships, classroom management, pedagogical skills, instructional strategies*

Introduction

Teaching internships are crucial components of physical education (PE) teacher preparation, allowing pre-service teachers to gain hands-on experience in authentic classroom environments. However, these internships can present considerable challenges that impact pre-service teachers' development. Heavy workloads and unclear expectations during internships caused anxiety among pre-service teachers (Gorospe, 2022; Lee et al., 2022; Nghia & Huynh, 2017). Other noted challenges include deficient mentorship, inadequate field experience, and difficulty applying theoretical knowledge (Moore, 2003; Reese, 2013; Canipe & Gunckel, 2019). Given the significance of high-quality teaching internships for pre-service teacher preparation, it is important to examine the obstacles faced by PE teacher candidates during these transitional experiences.

Practical experiences in teacher education provides a bridge between theory and real-world application. Teaching internships and student teaching help develop essential skills like planning, classroom management, and assessment, enhancing instructional competence (Shernoff et al., 2017; Qian & Youngs, 2015). High-quality practical experiences with mentoring and guided reflection boost effectiveness and retention, leading to more confident teachers (Evans-Andris et al., 2006; Hong et al., 2019). Early field experiences impact teaching commitment, highlighting the need for a developmental continuum of clinical practice (Kelly, 2013; Cribbs et al., 2020). Integrating coursework with fieldwork prepares future educators for the profession's complexities (Darling-Hammond, 2006; Zelkowski et al., 2023). Effective teacher education depends on incorporating practical experiences that equip educators to excel in the classroom and make a lasting im-

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pact on student learning.

Given the significance of high-quality teaching internships for pre-service teacher preparation, it is important to examine the obstacles faced by PE teacher candidates during these transitional experiences. As extended field experiences in authentic classroom settings, internships aim to link theory and practice through planning, teaching, assessment and reflection (Salviana et al., 2021; Moore, 2003). However, pre-service teachers often face challenges related to unclear expectations, deficient mentorship, inadequate preparation, and difficulty applying knowledge, which can cause anxiety and hinder development (DeAngelis, 2013; Canipe & Gunckel, 2019; Stripling et al., 2014; Jita & Munje, 2021). Furthermore, pre-service teachers may struggle with developing their professional identity, dealing with uncertainties, and balancing theory with practice during demanding internship experiences (Obiagu, 2023; Nghia & Tai, 2017; Kadroon, 2023). Targeted support through mentorship, reflective practices and aligning theoretical knowledge with practical experiences is crucial to help pre-service teachers successfully navigate their internships and overcome obstacles.

While there is extensive research on various aspects of teacher education and internships in general, only a limited number of studies have specifically focused on the challenges encountered by PE pre-service teachers during their internships (Silva et al., 2021). As Kadroon (2023) and Valencia et al., (2009) highlights, teaching internships present distinct challenges that can impact pre-service teachers' development of professional skills. Similarly, Nghia and Huynh (2017) examined the internship-related difficulties faced by pre-service teachers, emphasizing implications for teacher preparation programs. These studies reveal a gap concerning the unique challenges PE pre-service teachers experience in their internships. Although research shows the significance of quality mentoring and internships for pre-service teacher identity and efficacy (Prichard, 2017; Izadinia, 2015; Zhao & Zhang, 2017), there is minimal research delving into obstacles faced by PE teacher candidates specifically.

While studies have addressed challenges for pre-service teachers in various contexts like urban schools (Gaikhorst et al., 2016), agricultural education (Wells et al., 2019) and student teaching (Silva et al., 2021), the focus on pre-service PE teacher internship challenges remains limited. Further research is needed to examine these specific difficulties in order to provide tailored support and preparation for pre-service PE teachers entering the field. Thus, the objective of this study is to explore the challenges encountered by pre-service PE teachers during their internships, as discerned from their weekly journals.

This study examining pre-service PE teachers' internship challenges is vital for enhancing teacher preparation programs. Analyzing their reflective journals can provide insights into these challenges (Sahin et al., 2019) and inform targeted interventions to address problem areas (Silva et al., 2021; Soytürk & Öztürk, 2019). This will allow teacher educators to better support pre-service teachers in implementing effective instruction and successfully navigating demands. Additionally, it can guide mentorship initiatives to provide needed guidance and motivation (Clarà et al., 2019). Thus, this study exploring pre-service PE teachers' journals is significant for elucidating internship challenges, improving preparation programs, and ensuring quality education.

Methods

Research Design

This study used a qualitative phenomenological approach to explore the challenges faced by pre-service PE teachers during their internships. Phenomenology seeks to understand and describe individuals' lived experiences (Mapp, 2008), delving into their subjective experiences to gain insights into their views, opinions, feelings, and knowledge (Neubauer et al., 2019).

Participants and Setting

The study's participants were eight pre-service PE teachers from a university in northern Philippines, selected using purposive sampling (Etikan, 2016). This qualitative research technique involves establishing specific criteria and choosing participants who meet them to ensure the sample aligns with the study's objectives (Tuckett, 2004). The inclusion criteria for this study were: pursuing a Bachelor of Physical Education (BPEd) degree, being in their fourth and final year, and undertaking internships at private secondary schools in the area for the last two months of their studies. The study excluded pre-service PE teachers with internships in public secondary schools and those with incomplete journal submissions for the final two months.

Instrumentation

Data was collected from participants' weekly journals submitted over eight weeks during their teaching internships at private secondary schools. The journals were uploaded to a secure online platform (Google Classroom), accessible only to their college supervisor. Participant journals provided valuable insights into their thoughts, feelings, and experiences over time (Jacelon & Imperio, 2005; Rudrum et al., 2022). By offering detailed and rich information, journals captured the complex nature of participants' perspectives, serving as a window into their lived experiences (Rudrum et al., 2022).

Data Explication and Analysis

The study's primary data collection method involved analyzing and interpreting weekly journal entries from participants. Following the institution's guidelines, permission was obtained from the school's dean and informed consent was acquired from participants through a formal letter. Participants were assured of privacy, confidentiality, and anonymity, and their journals were securely stored and treated as confidential. Consent was obtained to use the journals for the study, maintaining participant anonymity.

The participants' journal data was analyzed using Braun and Clarke's (2006) thematic analysis method, a widely recognized qualitative approach for identifying patterns and themes (Forbes, 2021). This method involves a series of steps: familiarizing oneself with the data, generating initial codes, identifying potential themes, reviewing and refining themes, and formally defining and naming the themes (Braun & Clarke, 2006). Thematic analysis is a versatile approach that enables the identification of recurring topics and concepts in the data.

Results

The findings of this study are structured around key themes related to the challenges that pre-service PE teachers documented in their weekly journals during their internships. These include personal well-being and emotional strain, classroom management and student interactions, instructional practices and pedagogical challenges, and school environment and institutional factors.

Personal well-being and emotional strain

This theme highlights the challenges faced by pre-service PE teachers during their internships, which affected their personal well-being and emotional state. Table 1 presents codes that reveal various struggles, including health challenges, emotional vulnerability, and personal life demands, as illustrated by participant quotes.

Table 1. Personal Well-being and Emotional Strain

Codes	Sample Quoted Statements
Health challenges	"My biggest challenge is Friday's grueling teaching schedule, with only a 1-hour break, but I am determined to deliver engaging lessons despite fatigue and exhaustion". [PT8]
Emotional vulnerability	"My biggest challenge was overcoming nervousness about teaching PE subject. I found it demanding to develop engaging lesson plans and activities that promote active participation". [PT7]
Personal life interference	"I struggled to balance school and personal life, overwhelmed by financial stress, mental health struggles, and daily tasks, making it hard to eat, sleep, and function". [PT6]

Classroom management and student interactions

This theme demonstrates the critical challenges pre-service PE teachers encountered in classroom management and student engagement during internships. Table 2 illustrates the challenges they experienced in maintaining control, fostering meaningful student interactions, and navigating classroom dynamics.

Table 2. Classroom Management and Student Interactions

Codes	Sample Quoted Statements
Maintaining control	"Whenever I assign an activity, some students sleep or refuse to participate, citing exhaustion. Despite my reminders, they're stubborn and would not comply". [PT4]
Encouraging engagement	"Teaching PE subjects is my biggest obstacle. I struggle to create engaging lesson plans and activities that inspire participation and discussion, both in and out of the classroom". [PT2]
Navigating boundaries	"While fixing mats for a physical activity, a student suddenly hugged me from behind. I froze in shock, paused for a second, and was taken aback by the unexpected gesture". [PT2]

Instructional practices and pedagogical challenges

This theme encapsulates the challenges pre-service PE teachers confronted in their instructional practices and pedagogical approaches during their internships. Table 3 shows the codes that emerged, revealing complexities in planning and preparing lessons, adapting instruction, and evaluating student learning.

Table 3. Instructional Practices and Pedagogical Challenges

Codes	Sample Quoted Statements
Planning and preparation	"I am struggling to choose instructional materials for my dancing demonstration teaching. I worried about incomplete attire, so I opted for our PE uniform instead. Amidst exams, it is hard to focus on papers since our minds are preoccupied with demonstration preparation, adding to my anxiety". [PT6]
Instructional adaptability	"On my first day monitoring and facilitating, managing students across various grade levels and their diverse learning environments presented a significant challenge". [PT1]
Evaluation and assessment	"The sheer volume of submissions from large class sizes or multiple classes makes it challenging to provide thorough feedback and assessment within time constraints, compromising educational quality". [PT8]

School environment and institutional factors

This theme illustrates the challenges that pre-service PE teachers dealt within the broader school environment and the institutional factors that influenced their internship experience. Table 4 highlights the emergent codes that shed light on the lack of consistency, communication barriers, and institutional constraints these pre-service teachers navigated during their time in the field.

Table 4. School Environment and Institutional Factors

Codes	Sample Quoted Statements
Lack of consistency	"The ever-changing schedule is my only obstacle, as it disrupts my pre-set plans and requires adaptability". [PT6]
Communication barriers	"Despite clear directives from the PE Learning Area Coordinator, unforeseen scheduling conflicts regarding practice areas and upcoming intramurals have caused tension among some pre-service teacher interns, highlighting the persistence of miscommunication". [PT6]
Institutional constraints	"Managing four grade levels simultaneously in a shared space, with limited support from co-interns, is challenging. While I occasionally envy peers with more scheduling flexibility, I understand the crucial need for constant student supervision in this environment". [PT4].

Discussion

The purpose of this study is to examine the difficulties faced by pre-service PE teachers during their internships, as identified through their weekly journals. The first theme highlights the substantial impact of internship demands on pre-service PE teachers' well-being and emotional state. This is consistent with Maslach's burnout concept, which encompasses emotional exhaustion, depersonalization, and reduced personal accomplishment (Caraus, 2022). Participants shared challenges unique to PE teaching, such as health issues due to demanding schedules involving constant physical activity and demonstration, along with emotional vulnerability arising from anxieties about creating engaging lessons for diverse learners and managing student behavior in dynamic PE settings. These findings align with research emphasizing the distinctive stressors PE teachers face, including ensuring student safety during high-energy activities and adapting lessons to various learning styles and physical abilities (Åsebø et al. 2020; Trad et al. 2021). The analysis indicated a critical need to incorporate well-being support and coping strategies tailored to PE's specific demands within teacher education programs, enabling future PE teachers to manage stress and prioritize their well-being, ultimately fostering a more sustainable and effective workforce committed to promoting physical literacy and healthy lifestyles.

The second theme underscores the significant challenges pre-service PE teachers encounter in classroom management and student interaction during internships. Bandura's Social Learning Theory posits that learning occurs through observation and modeling (Hardiyana & Maemonah, 2023), highlighting the need for pre-service teachers to observe and practice effective PE management strategies. Participants reported difficulties in managing student defiance and disengagement, creating engaging activities, and maintaining appropriate student-teacher boundaries. These findings are consistent with previous research showing that classroom management in PE requires specialized skills and strategies (Sanetti et al., 2017; Gage et al., 2017). Effective PE teachers use movement-based activities and transitions to minimize downtime and proactively manage their behavior (Weaver et al., 2017; Harun et al., 2015). Thus, PE teacher education programs must emphasize explicit instruction and mentored practices in proactive behavior management, differentiated instruction techniques, and strategies for establishing clear, respectful boundaries to prepare future PE teachers for positive and productive learning environments.

The third theme focuses on the difficulties pre-service PE teachers encounter in instruction and pedagogy. This corresponds to Schön's idea of reflection-in-action, which highlights the importance of adapting in real-time (Segal, 2023). Journal entries revealed that pre-service teachers grappled with lesson planning for diverse learners in inclusive settings, adapting instruction to varied physical abilities, and managing assessments and feedback in active learning environments. These findings resonate with the literature that emphasizes the complexities of PE instruction and the need for ongoing reflection (Mendoza & Calabia, 2024; García-Hermoso et al., 2020). Yin et al. (2020) and Sevil-Serrano et al. (2020) underscore the importance of catering to diverse learners, while Modell and Gerdin (2021) highlight the role of ongoing assessment in effective PE instruction. Therefore, PE teacher education programs should prioritize practical experiences, such as micro-teaching, peer observation, and structured feedback, focusing on differentiated instruction, assessment in active settings, and reflective practices to support continuous growth.

The last theme addresses the challenges faced by pre-service PE teachers as they navigate the school environment and deal with the institutional factors. This aligns with Bronfenbrenner's Ecological Systems Theory (Perron, 2017), which emphasizes the significant impact of various environmental systems on development. The journals of pre-service teachers revealed frustration with inconsistent schedules, breakdown in communication, and limited resources and support within their placements. These experiences are consistent with research that emphasizes how the school context, including organizational culture, administrative support, and mentoring relationships, greatly influences novice teachers' experiences and the formation of their professional identities (Bertram, 2023; Çakmak et al., 2018; Saleem et al., 2021; Hanifah, 2022; Hou et al., 2023). Therefore, effective preparation for PE teachers requires stronger partnerships between universities and schools. This will help provide consistent schedules, clear communication channels, and adequate resources to support pre-service teachers, as they navigate the complexities of the school environment.

Conclusion

This study aimed to explore the various challenges encountered by pre-service PE teachers during internships, which greatly influence their well-being, classroom management approaches, instructional practices, and overall school experiences. These findings underscore the pressing need for PE teacher education programs to prioritize well-being support, enhance PE-specific classroom management training, and offer more opportunities for practical experience in diverse settings. It is crucial to strengthen the collaboration between universities and schools to ensure consistent schedules, effective communication, and adequate resources for pre-service teachers. By addressing these challenges and fostering collaborative support systems, the field can better equip future PE educators to promote physical literacy, health, and well-being among all students. This pilot-study provides valuable insights into teacher education reform and contributes to the advancement of a more resilient and effective PE workforce.

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Conflict of Interest

The authors reported no known conflicts of interest relating to the research, analysis, or publication of this study's findings.

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Journal of Anthropology of Sport and Physical Education

ORIGINAL SCIENTIFIC PAPER

The Effect of Exercises with Blood Flow Restriction in the Limbs on the Development of Muscle Strength and Hypertrophy: A Pilot Study

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Abstract

Weight training with regulated blood flow in the limbs is characterized by low load intensity ranging from 30-50% of the one repetition maximum. The aim of the study was to assess the effect of weight training with regulated blood flow in the limbs on changes in muscle strength and hypertrophy. The research sample consisted of 5 participants aged 26.40±7.16 years who performed 10-week intervention program. The weekly microcycle consisted of three training sessions, which intensity was regulated by inflatable cuffs placed on proximal parts of upper and lower limbs. Body composition was assessed with InBody 720. Muscle strength of knee and elbow flexors and extensors was assessed with Cybex HUMAC NORM isokinetic dynamometer at four speeds ranging from 60-240°·s-1, supplemented by front squat and bench press with emphasis on speed during the concentric phase of the movement. The results showed an increase in knee flexor muscle strength that was not statistically significant. The present pilot-study points to the need for further verification of methods how to use regulated blood flow in training related to muscle strength and hypertrophy.

Keywords: *weight training, isokinetic dynamometry, body composition, KAATSU*

Introduction

The increase in muscle strength and hypertrophy should be related to the optimization of training variables applied in weight training exercises (Scheonfeld, Grgic, Van Ery & Plotkin, 2021). One of the main recommendations for the development of muscle strength and hypertrophy in weight training include setting the load intensity between 70-85% of the one repetition maximum (1RM) for 8-12 repetitions in 1-3 sets per exercise (Kraemer & Ratamess, 2004). On the other hand, it has been shown that using blood flow restriction (BFR) in the limbs, can develop muscle strength and hypertrophy even at load intensities lower than 50% of 1RM (Kim et al., 2017; Lixandrao at al., 2018; Grøenfeld, Nielsen, Mieritz, Lund & Aagard, 2020). In such a method of weight training, blood flow is regulated by a device that is similar to a medical pressure gauge. Using external cuffs that are fixed on the proximal parts of the upper and consequently the lower limbs, the pressure is determined, which can be considered as the degree of load intensity (Slysz, Stultz & Burr, 2016). The increase in muscle strength and hypertrophy by blood flow regulated exercise (BFR) is induced by multiple mechanisms (Loennekke, Wilson & Wilson, 2010). Loenneke, Fahs, Rossow, Abe and Bemben (2012) describe increased metabolic stress, greater involvement of fast-twitch muscle fibers, and increased cellular swelling as three determining mechanisms. As a result of blood flow restriction to the limbs, metabolic stress is induced on the basis of the accumulation of waste products of metabolism and tissue hypoxia. Metabolic stress induced by muscle work with blood flow restriction increases amino acid transport into muscle cells, resulting in muscle proteosynthesis (Wagner, 1996). It also has been shown that metabolic stress reactively increase growth hormone levels (Suga et al., 2010). The reactive increase in growth hormone levels is considered by Takarada et al. (2000) to be the primary mechanism for increasing in muscle strength and hypertrophy. Accumulated metabolic waste products in the muscle increase the involvement of fast-twitch muscle fibres (Yasuda et al., 2010). Although muscle

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hypertrophy has been demonstrated in all types of muscle fibers, according to Wagner (1996), fast-twitch muscle fibers have a greater potential to hypertrophy. The aim of this pilot study was to assess the effect of weight training with regulated blood flow in the limbs on changes in muscle strength and hypertrophy.

Methods

Participants

The experimental design is demanding in terms of individual approach, which was reflected in the research sample size. Five participants were included in the pilot study. It was necessary to supervise the correct application of inflatable cuffs on the proximal parts of the limbs and compliance with the set pressure in the cuffs, which determined the exercise intensity in the form of controlled blood flow restriction in the limbs. The research sample consisted of 3 females and 2 males with a mean age of 26.40±7.16 years. Before the intervention, participants had been regularly performing weight training and amateur combat training (boxing or karate) for more than one year with a frequency of 3 training session per week.

Table 1. Description of the research sample

Participants	Gender	BH (cm)	BW (kg)	SMM (kg)	BFM (kg)	VFA (cm^2)
P01	♀	171	60.5	28.6	9.6	20.4
P02	♀	168	62.4	27.1	13.2	57.9
P03	♀	170	54.1	26.3	6.9	23.0
P04	♂	178	65.6	37.8	6.7	21.2
P05	♂	183	86.7	41.8	14.0	80.3

Note. BH: body height; BW: body weight; SMM: skeletal muscle mass; BFM: body fat mass; VFA: visceral fat area; ♀: females; ♂: males

Procedures and measurements

Before the pretest, participants were informed and consented to the purpose and procedures of testing, which was conducted in accordance with the ethical standards of the Declaration of Helsinki (Harris, Macsween & Atkinson, 2017). The research was approved by the ethics committee of the University of Presov and ethics committee of Hospital AGEL Košice - Šaca a. s. Body height was measured by the BSM170 stadiometer (Biospace, Seoul, North Korea) and body composition via bioelectrical impedance by InBody 720 (Biospace, Seoul, North Korea). Among the body composition parameters, we assessed body weight (BW), skeletal muscle mass (SMM), body fat mass (BFM) and visceral fat area (VFA). To ensure the objectivity of the results, the pretest and posttest were taken at the same time of the day. Subsequently, participants performed a 10-minute pretest warm-up on a cycle ergometer, with the addition of mobilization and isometric exercises. Local muscle strength was measured by a Cybex HUMAC NORM isokinetic dynamometer (Cybex NORM®, Humac, CA, United States) with emphasis on the extensors and flexors of the knee and elbow joints. Local muscle strength of knee joint extensors and flexors was measured in concentric muscle contraction in a range of motion of 90° at 60°·s^{-1}, 120°·s^{-1}, 180°·s^{-1}, and 240°·s^{-1}. Local strength of the elbow extensors and flexors was assessed in concentric muscle contraction in a range of motion of 120° at 60°·s^{-1}, 180°·s^{-1}, and 240°·s^{-1}. Testing consisted of three trials with maximal effort, preceded by two trials with submaximal effort to familiarize with the test procedure. Visual feedback and verbal motivation were provided during the execution of the muscle strength tests on the isokinetic dynamometer to ensure maximal stimulation of moral-volitional qualities. The level of strength abilities was also measured by front squat and bench press with emphasis on the speed of the concentric phase of the movement using the FiTROdyne Basic Peak Power LCD device (FiTRONiC, s.r.o., Slovakia). Testing consisted of two consecutive repetitions performed with maximal effort. Increasing the load continued until the speed dynamic regime decreased under the minimum dumbbell speed in the concentric phase of the movement at 0.7 m·s^{-1} (Zatsiorsky & Kraemer, 2006).

Intervention

The intervention consisted of weight training sessions performed 3 times per week for 10 weeks. The training sessions consisted of dynamic strengthening exercises with a load intensity of 40% 1RM using regulated blood flow in the limbs. Blood flow was regulated using inflatable cuffs KAATSU AIRBANDS (KAATSU Global Inc., CA, United States) placed on the proximal parts of the upper or lower limbs and device KAATCU C3 (KAATSU Global Inc., CA, United States). The baseline pressure applied to the limbs was set at 200 SKUs (Standard Kaatsu Units), increasing linearly by 20 SKUs every week. The strength-

Monday

Upper limbs
- *single arm incline bench press*
- *prone incline dumbbell row*
- *unilateral shoulder press*
- *dumbbells arms forward*

Lower limbs
- *split squat*
- *unilateral deadlift*
- *unilateral hip thrust*
- *unilateral calf raises*

Wednesday

Upper limbs
- *bench press*
- *prone barbell row*
- *unilateral shoulder press*
- *dumbbells arms forward*

Lower limbs
- *front squat*
- *deadlift*
- *dorsal flexion of ankle*
- *calf raises*

Friday

Upper limbs
- *seated cable row*
- *seated cable arm abduction*
- *underhand cable biceps curl*
- *cable triceps pushdown*

Lower limbs
- *seated leg press*
- *seated leg curl*
- *lying leg curl*
- *calf raises on smith machine*

FIGURE 1. Intervention program

ening exercises applied in the weekly microcycle are presented in Figure 1.

The strength exercises were performed in 3 sets of 15 repetitions with 1 minute rest between the sets. The applied exercises were performed in a horizontal sequence, which is characterized by performing all sets of one exercise before moving to other exercise.

Statistical analysis

Based on the small size of the research sample, the median was used as a measure of central tendency and the quartile deviation as a measure of variability. Statistical analysis was performed using SPSS Statistics 20.0 software (IBM, Armonk, USA).

Results

Inter-individual comparison of input and output measurements of skeletal muscle mass showed the observed differences. In one case, there was a 0.7 kg increase in the proportion of muscle mass in the female participant. In the other participants, there was a decrease in skeletal muscle by an average of 0.95 kg, and in the male participants by 2.15 kg. The trend was reflected by an increased proportion of fat mass on average of 1.1 kg in females and 1.45 kg in males. The proportion of visceral fat increased from 33.8 cm2 to 42.9 cm2 in women and decreased from 50.7 cm2 to 48.7 cm2 in men. A visual interpretation showing the pretest and posttest muscle strength measurements of the men's knee joint extensors and flexors is presented in Figure 2.

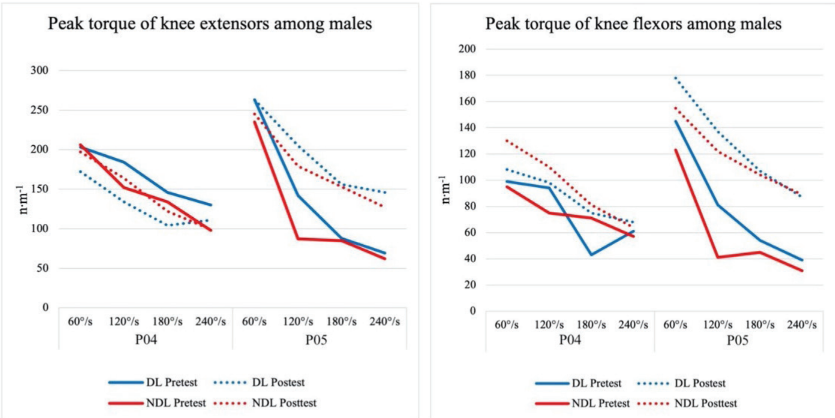

FIGURE 2. Peak torque of knee extensors and flexors in male sample. DL: dominant limb; NDL: non-dominant limb

Inter-individual comparison showed a decrease in muscle strength of the knee joint extensors of dominant and nondominant limb at angular velocity 60°·s^{-1} by 8 n·m^{-1} in both participants. In participant P04 a decrease of 23 n·m^{-1} in muscle strength in both limbs at angular velocity 180°·s^{-1} was similarly noted. In the second case, muscle strength increase of 72 n·m^{-1} were recorded at 120°·s^{-1}, 180°·s^{-1} and 240°·s^{-1} angular velocities. The analysis of knee joint flexor muscle strength showed improvement on dominant and non-dominant limb in both subjects at all angular velocities measured. The highest increase in knee joint flexor

Table 2. Descriptive statistics of pretest and posttest measurements of peak torque of knee extensors and flexors in female sample

Variables			Pretest	Posttest
			Median±Quartile deviation (min/max)	
DL	60°·s^{-1} KE	n·m^{-1}	157.00±4.75 (146.00/165.00)	152.00±7.25 (127.00/156.00)
	60°·s^{-1} KF		95.00±8.00 (76.00/108.00)	89.00±5.50 (84.00/106.00)
	120°·s^{-1} KE		102.00±8.75 (95.00/130.00)	102.00±6.75 (96.00/123.00)
	120°·s^{-1} KF		75.00±7.75 (57.00/88.00)	76.00±7.25 (65.00/94.00)
	180°·s^{-1} KE		85.00±4.75 (98.00/79.00)	92.00±6.50 (69.00/95.00)
	180°·s^{-1} KF		54.00±4.75 (52.00/71.00)	58.00±5.75 (56.00/79.00)
	240°·s^{-1} KE		72.00±1.25 (68.00/73.00)	75.00±4.00 (60.00/76.00)
	240°·s^{-1} KF		49.00±4.50 (43.00/61.00)	50.00±6.50 (49.00/75.00)
NDL	60°·s^{-1} KE		138.00±12.00 (127.00/175.00)	144.00±3.25 (133.00/146.00)
	60°·s^{-1} KF		83.00±8.75 (69.00/104.00)	91.00±9.50 (73.00/111.00)
	120°·s^{-1} KE		98.00±7.75 (92.00/123.00)	99.00±6.75 (95.00/122.00)
	120°·s^{-1} KF		58.00±10.25 (54.00/95.00)	66.00±10.75 (57.00/100.00)
	180°·s^{-1} KE		75.00±5.75 (72.00/95.00)	80.00±5.25 (73.00/94.00)
	180°·s^{-1} KF		50.00±6.50 (46.00/72.00)	50.00±6.50 (50.00/76.00)
	240°·s^{-1} KE		58.00±8.00 (43.00/75.00)	65.00±3.75 (60.00/75.00)
	240°·s^{-1} KF		41.00±7.75 (37.00/68.00))	46.00±6.00 (45.00/69.00)

Note. DL: dominant limb; NDL: non-dominant limb; KE: knee extensors; KF: knee flexors muscle strength was observed in the non-dominant limb at angular velocity of 120°·s^{-1} by 26.4 n·m^{-1}. On the contrary, the lowest increase was observed at angular velocity of 60°·s^{-1} on the dominant limb by 8.4 n·m^{-1}.

Comparison of the medians showed an increase in muscle strength of the knee joint extensors of non-dominant limb at all angular velocities measured. In the inter-individual comparison, the increase was demonstrated in all participants only at the 240°·s^{-1} angular velocity. Comparing the knee joint flexors median values, an improvement was noted at all angular velocities studied except 60°·s^{-1} on the dominant limb and 180°·s^{-1} on the non-dominant limb, where no change occurred. Inter-individual comparison showed an increase in muscle strength in all participants at all angular velocities except at 60°·s^{-1} on the dominant limb, where two participants showed a decrease in muscle strength. A visual interpretation showing the pretest and posttest muscle strength measurements of the men's elbow joint extensors and flexors is presented in Figure 3.

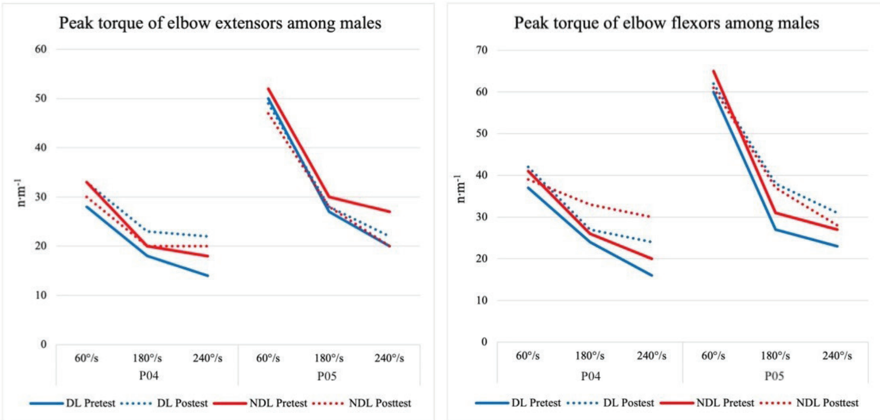

FIGURE 3. Peak torque of elbow extensors and flexors among males. DL: dominant limb; NDL: non-dominant limb

Inter-individual comparison showed a decrease in muscle strength of elbow joint extensors in participant P04 at angular velocity 60°·s^{-1} by 3 n·m^{-1} on the non-dominant limb. At all other velocities measured, there was an improvement in the performance of the participant. In participant P05 there was a decrease in muscle strength at angular velocity 60°·s^{-1} on both limbs by 3 n·m^{-1}. At the same time, there was a decrease in muscle strength of the non-dominant limb at 120°·s^{-1} and 180°·s^{-1} angular velocities by 4.5 n·m^{-1}, whereas there was an increase in muscle strength of the dominant limb at these velocities by 1.5 n·m^{-1} on average. Participant P04 showed an improvement in elbow flexor muscle strength at all angular velocities measured by 5.8 n·m^{-1}. Similarly, participant P05 showed an improvement at all velocities observed by 5.6 n·m^{-1}, except for the non-dominant limb at angular velocity 60°·s^{-1}, where a decrease in muscle strength by 4 n·m^{-1} was noted.

Table 3. Descriptive statistics of pretest and posttest measurements of peak torque at elbow extensors and flexors in female sample

Variables			Pretest	Posttest
			Median±Quartile deviation (min/max)	
DL	60°·s-1 EE	n·m^{-1}	20.00±4.00 (19.00/35.00)	26.00±1.25 (22.00/27.00)
	60°·s^{-1} EF		31.00±2.50 (23.00/33.00)	31.00±1.50 (28.00/34.00)
	180°·s^{-1} EE		16.00±0.25 (15.00/16.00)	18.00±1.00 (16.00/20.00)
	180°·s^{-1} EF		19.00±1.50 (19.00/20.00)	20.00±1.25 (19.00/24.00)
	240°·s^{-1} EE		14.00±5.00 (15.00/19.00)	18.00±1.00 (15.00/19.00)
	240°·s^{-1} EF		16.00±1.00 (12.00/16.00)	15.00±3.50 (5.00/19.00)
NDL	60°·s^{-1} EE		23.00±1.00 (19.00/23.00)	28.00±2.50 (20.00/30.00)
	60°·s^{-1} EF		28.00±2.00 (23.00/31.00)	26.00±2.00 (20.00/28.00)
	180°·s^{-1} EE		16.00±0.50 (15.00/19.00)	16.00±1.00 (15.00/19.00)
	180°·s^{-1} EF		18.00±1.00 (15.00/19.00)	19.00±1.75 (19.00/24.00)
	240°·s^{-1} EE		15.00±0.75 (12.00/16.00)	15.00±0.75 (12.00/16.00)
	240°·s^{-1} EF		18.00±1.50 (14.00/20.00)	18.00±2.75 (9.00/20.00)

Note. DL: dominant limb; NDL: non-dominant limb; EE: elbow extensors; EF: elbow flexors

Comparing differences in female sample, an increase in the elbow joint extensors muscle strength of the dominant limb at all angular velocities was measured, while increases at 60°·s^{-1} were noted in the non-dominant limb. In the inter-individual comparison, an increase in muscle strength was shown in all participants only on the non-dominant limb at angular velocity of 60°·s^{-1}. On the other hand, when comparing the median values of elbow joint flexors, improvement was observed only at 180°·s^{-1} angular velocity on the dominant and non-dominant limb. Inter-individual comparison did not show such increase in muscle strength in only one participant on the dominant limb. In terms of bilateral movements during front squat and bench press, the following differences can be shown by comparing the pretest and posttest values. Two female participants showed an increase in velocity during the concentric phase of the movement by an average of 0.9 m/s, while one participant showed no change in performance. An improvement of 0.14 m/s was recorded in only one participant, with no changes in performance recorded in the other participant. On the contrary, the effect of strength training with regulated blood circulation in the limbs was demonstrated on velocity changes during the concentric phase of movement in the bench press lying position in only one participant by 0.04 m/s. A decreased velocity by 0.08 m/s was similarly noted in only one participant, with no changes in performance in the latter case. In men, no changes in velocity were recorded during the concentric phase of movement in the bench press.

Discussion

This pilot-study investigated the effect of weight training with regulated blood flow in the limbs on changes in muscle strength and hypertrophy. In relation to muscle hypertrophy, a decrease in the level of skeletal muscle mass was not observed only in one female participant. Second, due to weight training with regulated blood flow in the limbs, the level of muscle strength of knee extensors decreases at angular velocity $60°\cdot s^{-1}$. Contrarily, the level of muscle strength of knee flexors increases at angular velocity $240°\cdot s^{-1}$. In addition the level of muscle strength of elbow extensors and flexors increases at angular velocity $180°\cdot s^{-1}$.

Comparing the results of our study with Miller, Tirko, Shipe, Sumeriski and Moran (2021) which confirm the positive effect of training with regulated blood flow in the limbs on muscle hypertrophy, our results point to decrease of skeletal muscle mass. Non-significant improvement in muscle circumference and thickness after exercising with BFR was also noticed in the of study of Thiebaud, Yasuda, Loenneke and Abe (2013). Pressure caused by application of inflatable cuffs on limbs during weight training induces specific conditions in which muscle failure occurs even at low load intensities. It shows that increased cellular swelling may be a reactive, as well as an adaptive change in muscle hypertrophy, due to the placed cuffs. It is a hypoxic environment that enhances the training effect in exercising muscle (Takada et al., 2012). Cook, Kilduff and Beaven (2014) suggest that higher recruitment of fast twitch fibers during the weight training with regulated blood flow enhances the muscle hypertrophy. Mechanical tension and metabolic stress seem to be the factors primarily responsible for hypertrophic adaptations following blood flow restriction training. Weight training with regulated blood flow in the limbs can enhance muscle hypertrophy in case of low level of muscle strength. However, the relative extent to which these specific mechanisms are induced by the factors in weight training with regulated blood flow in the limbs, as well as their range of involvement in BFR weight training-induced muscle hypertrophy, requires further exploration (Pearson & Hussain, 2015). In relation to body fat, we observed non-congruent results in comparison with findings of Lixandrão et al. (2018) who showed a decrease in fat mass.

In relation to muscle strength our results are in contrast with previous findings presented by Early et al. (2018), Hill et al. (2020) and Bradley, Bunn, Feito and Myers (2022), who reported an increase in the level of maximal strength due to weight training with regulated blood flow. The study of Hill et al. (2020) compared 4 weeks isokinetic low-load weight training with and without BFR. The results showed greater increases in concentric peak torque with application of BFR in training sessions. Comparative analysis of Yang et al. (2022) showed that training with regulated blood flow in the limbs increases the knee extensors and flexors isokinetic torque, muscle strength of lower limbs and maximal strength in squat. Regarding to applicated load intensity and findings of our study, Manini and Clark (2009) emphasize that load measured by 1RM and maximal voluntary contraction is an important factor influencing the training effect. According to them, the recommended load intensity for optimal training effect is from 20% to 30% of 1RM. Another study by Spitz et al. (2023) compared isotonic and isokinetic strength training. The findings revealed that resistance training led to significant increases in both specific and non-specific muscle strength, with a smaller effect size associated with non-specific muscle strength. The combination of BFR with weight training showed significant benefits in terms of muscle strength, even at low load intensity, and it is comparable or more efficient than strength training (Wilk et al., 2018). The results in the studies by Cook et al. (2014) and Bowman et al. (2019) showed congruent findings with our research in relation to speed strength. In addition, Hill et al. (2020) concede that the weight training with regulated blood flow in the limbs positively affects the level of explosive power compared to weight training without blood flow regulation. On the other hand, it is necessary to emphasize that weight training with regulated blood flow in the limbs with low load intensity does not affect the level of muscle strength as strength training with high load intensity (Yasuda et al., 2011).

Conclusion

Based on the results it seems that the weight training with regulated blood flow restriction does not affect muscle hypertrophy in athletes. Therefore, in following research is necessary to take into account nutritional habits of participants, which can significantly affect muscle hypertrophy. In maximal strength development, it shows that weight training with regulated blood flow in the limbs at load intensity at 40% of 1RM is insufficient. That points to the need for modification of external load and more vigorous monitoring of internal load during weight training with regulated blood flow in the limbs. Contrary to speed strength, the results point to an increase. This creates scopes for the use of BFR in weight training at a load intensity of 40% of 1RM without emphasis on speed movement during exercising especially in microcycles focused on speed strength development. The findings of the present pilot-study point to the need for further verification of methods how to use regulated blood flow in training related to muscle strength and hypertrophy.

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Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial and financial relationships that could be construed as a potential conflict of interest.

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JASPE Journal of Anthropology of Sport and Physical Education

ORIGINAL SCIENTIFIC PAPER

Comparative Analysis of Motor Skills and Morphological Characteristic of the Young Female Athletes

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Abstract

Handball and volleyball are quite different sports. Thus, this research was inspired by these differences, by similar previous research, and the aspire to see if there are differences between the performances of young female athletes that play handball and volleyball. The aim of this research is to perform a comparative analysis of motor skills and morphological characteristics of young female athletes, handball and volleyball players. The complete sample consisted of 50 female athletes. One study group is composed of 25 female handball players, who are members of the women's handball club „Niksic". And the second study group is composed of 25 female volleyball players, who are members of the women's volleyball club „Volley Star". All female athletes are aged 12 to 14 and they have been training handball or volleyball for at least 2 years. In order to assess morphological characteristics and motor abilities, fourteen measures were applied to the sample. A t-test was used to determine statistically significant differences between study groups. In conclusion, there are statistically significant differences in terms of motor skills and morphological characteristics between young female handball and volleyball players.

Keywords: *handball, volleyball, motor skills, morphological characteristics*

Introduction

A tendency for improvement and measurement of their own abilities and characteristics, which can be developed under the influence of the training process is one of the basic motives that makes people to play sports (Bjelica, 2005). Research highlights the differences between athletes who play different sports. For instance, a study by Masanovic, Gardasevic, and Bjelica (2021) showed that volleyball players had significantly greater body height compared to handball players, while handball players had significantly higher body weight and a greater percentage of muscle mass compared to volleyball players. Similar results were obtained by Masanovic, Milosevic, and Corluka (2018), who also tested volleyball and handball players. Another study by Simonek, Horicka, and Hianik (2017) found that handball players performed better in the 30m sprint test compared to volleyball players. Research by Pena, Moreno-Doutres, Coma, Cook, and Busca (2016) showed that handball players had better agility compared to volleyball players. The study by Zekic, Robert, Vucetic, Vlatko, Pejcic, and Tena (2017) demonstrated that female handball players had greater aerobic endurance compared to female volleyball players, considering the sport's demands and training processes.

Volleyball is a linear interval game requiring players to perform short, high-intensity actions followed by periods of low-intensity activities (Gabbett, Georgieff, and Domrow, 2007; Majstorovic, Nesic, Grbic, Savic, and Dopsaj, 2019). It is considered a sport where power, strength, and explosiveness dominate, often demonstrated through various types of jumps and the ability to spike and serve the ball at high speeds. Over time, volleyball has evolved from a refined technical game to a strong and aggressive one (Selinger, 1987), putting the opposing team at a disadvantage.

Handball is a sport that falls under polystructural sports activities, as it includes all natural movement forms along with cyclic and acyclic movement structures. Players' movements, which manifest in different rhythms, methods, and intensities, relate to cyclic movements often interrupted by acyclic movements (jumps,

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throws, etc.). Such characteristics make handball one of the most complex sports (Foretic and Rogulj, 2007). This sport provides opportunities for the coordinated development of all muscle groups, activating various functional potentials that enhance all motor skills (Foretic and Rogulj, 2007). Morphological characteristics are significant for achieving top results in this game (Sibila and Pori, 2009). Marvic (2006) considers that a top handball player must possess the characteristics of a modern decathlete.

The primary goal of this research is to determine whether there are statistically significant differences between the motor skills and morphological characteristics of young female handball and volleyball players.

Methodology

The total sample of respondents comprises 50 girls, divided into two sub-samples. The first sub-sample consists of 25 handball players aged 12 to 14, who have been in continuous training for at least two years in the women's handball club "Niksic." The second sub-sample includes 25 volleyball players aged 12 to 14, who have also been in continuous training for at least two years in the women's volleyball club "Volley Star."

The sample of measuring instruments for assessing morphological dimensions was conducted according to the standardized ISAK manual (Marfell-Jones, Olds, Stew, and Carter, 2006). The selected variables are: body height (ATV), body weight (ATT), arm span (ARR), hand length (ADS), waist circumference (AOS), hip circumference (AOK), and Body Mass Index (BMI). The sample of measuring instruments for assessing motor skills was conducted according to the model by Bala et al. (2007), including: 20m run (MT2), high jump (MSV), standing long jump (MSD), standing on one leg test (MSN), sit and reach test (MTP), trunk lift test (MPT), and push-ups (MTS). This battery of measuring instruments was constructed to meet the research's needs and objectives.

The obtained results in this research were processed using descriptive and comparative statistical methods. The statistical significance of differences in selected variables was determined using a t-test for independent samples with a statistical significance level set at $p<0.05$.

Results

Tables 1, 2, 3, and 4 present the basic descriptive statistical parameters of the morphological characteristics and motor skills of handball and volleyball players, including calculated values of central and dispersion tendencies: arithmetic mean (Mean), standard deviation (Sd), minimum (Min) and maximum (Max) values, range (R), skewness coefficient (Sk), and kurtosis coefficient (Ku).

Tabela 1. Descriptive Statistics of Morphological Characteristics of Female Handball Players

Variables	N	Min	Max	Mean	Sd	R	Sk	Ku
ATV	25	154.00	179.00	167.42	6.39	25.00	-0.25	-0.17
ATT	25	40.60	73.60	56.06	10.22	33.00	0.29	-1.18
ARR	25	154.00	183.00	168.00	7.29	29.00	-0.02	-0.17
ADS	25	16.00	20.00	18.20	1.00	4.00	-0.28	0.15
AOS	25	59.00	88.00	67.28	7.58	29.00	1.20	0.93
AOK	25	78.00	105.00	90.20	8.26	27.00	0.40	-1.11
BMI	25	15.80	25.65	19.79	3.20	9.85	0.46	-1.30

Legend: N - number of entities; Min - minimum results; Max - maximum results; Sd - standard deviation; R - range; Sk - skewness measure; Ku - kurtosis measure; ATV - body height; ATT - body weight; ARR - arm span; ADS - hand length; AOS - waist circumference; AOK - hip circumference; BMI - Body Mass Index

Table 1 shows the processed results obtained by measuring the morphological characteristics of handball players. The analysis begins with parameters describing the Gaussian curve. Skewness (Sk) represents a measure of symmetry. According to the results in Table 1, the results are close to zero, with the hip circumference (AOK) standing out with Sk = 1.20. However, we can conclude that the skewness results are not statistically significant as they do not exceed ±2, ranging from -0.28 to 1.20. For an ideally symmetrical curve, skewness is zero, indicating no skewness, which is not the case for the results in this table. Kurtosis represents the Gaussian curve's peak curvature. The kurtosis column shows values ranging from -1.30 to 0.93, with parameters such as BMI = -1.30, body weight (ATT) = -1.18, and hip circumference (AOK) = -1.11 being most distant from zero but still statistically insignificant. Based on the skewness and kurtosis values, we can conclude that all results indicate a normal distribution. The Gaussian curve's shift is minimal, so each variable is slightly flattened or elongated but statistically insignificant. Analyzing the standard deviation (Sd) and its relationship with the arithmetic mean (Mean), we can conclude that there are no statistically significant results. In Table 1, one variable with the smallest range is hand length (ADS = 4.00), while the variable with the largest range is body weight (ATT = 33.00). Other variables have optimal values between the minimum and maximum.

Table 2 describes the descriptive statistics of the motor skills of handball players. The skewness values range from -0.25 to

Tabela 2. Descriptive Statistics of Motor Skills of Female Handball Players

Variables	N	Min	Max	Mean	Sd	R	Sk	Ku
MT2	25	2.95	4.50	3.65	0.28	1.55	0.31	3.08
MSV	25	15.00	44.00	29.20	8.37	29.00	-0.25	-0.83
MSD	25	140.00	230.00	178.60	21.15	90.00	0.36	0.25
MSN	25	1	2	1.28	0.45	1	1.04	-0.99
MTP	25	1	14	6.72	4.19	13	-0.05	-1.37
MPT	25	13	22	16.96	2.28	9	0.19	-0.31
MTS	25	2	35	15.84	10.69	33	0.42	-0.91

1.04, indicating no statistically significant results. Kurtosis represents the measure of homogeneity and is related to empirical result variability in a statistical series. The table shows that the 20m run variable (MT2) stands out with MT2 = 3.08, while other kurtosis values are close to zero, with the smallest value being trunk flexion (MTP) at MTP = 1.37, which is statistically insignificant. The 20m run (MT2) is statistically significant and shows that the Gaussian curve is mesokurtic. Analyzing skewness and kurtosis, we can conclude that the Gaussian curve's shift is minimal and statistically insignificant in all variables except for MT2, where the curve is ideally mesokurtic. Analyzing the standard deviation (Sd) column and its relationship with the arithmetic mean (Mean), we can conclude that there are no statistically significant results.

Analyzing Table 3, we see that the skewness column shows that the waist circumference (AOS) variable is statistically significant (AOS = 2.17). This indicates that the waist circumference measurements in this group are below average, with the Gaussian curve showing positive asymmetry. The smallest value is BMI (-0.33), which is statistically insignificant. Other variable values are close to zero with no significant deviations. The kurtosis column shows that the waist circumference (AOS) variable is statistically significant (AOS = 7.18). Since the kurtosis value is greater than 3, the Gaussian curve is leptokurtic, indicating result homogeneity for this variable and a higher Gaussian curve peak. The lowest kurtosis value is hip circumference (AOK) at -1.19, which is statistically insignificant. The results show that the waist circumference (AOS) values (Sk = 2.17, Ku = 7.18) indicate positive asymmetry and greater curvature, indicating result homogeneity. Other variable results are statistically insignificant, with minimal Gaussian curve deviations from normality. When analyzing the standard deviation (Sd) and its relationship with the arithmetic mean (Mean), we find no statistically significant results. The range (R) column shows that hand length (ADS) has the smallest value (ADS = 3.00), while body height (ATV) has the largest range (ATV = 22.00). Other variables have approximately similar ranges.

Tabela 3. Descriptive Statistics of Morphological Characteristics of Female Volleyball Players

Variables	N	Min	Max	Mean	Sd	R	Sk	Ku
ATV	25	156.00	178.00	167.44	5.59	22.00	-0.13	-0.41
ATT	25	48.10	67.50	56.61	5.63	19.40	0.42	-0.85
ARR	25	157.00	178.50	168.31	6.07	21.50	-0.08	-0.53
ADS	25	17.00	20.00	18.51	0.93	3.00	-0.24	-0.69
AOS	25	60.00	80.00	65.32	3.97	20.00	2.17	7.18
AOK	25	85.00	98.00	92.04	3.94	13.00	-0.22	-1.19
BMI	25	17.21	22.10	20.07	1.42	4.89	-0.33	-1.09

Tabela 4. Descriptive Statistics of Motor Skills of Female Volleyball Players

Variables	N	Min	Max	Mean	Sd	R	Sk	Ku
MT20	25	3.40	4.26	3.80	0.19	0.86	-0.07	0.43
MSV	25	10.00	45.00	32.04	10.02	35.00	-0.81	-0.46
MSD	25	130.00	203.00	174.72	16.68	73.00	-0.73	0.82
MSN	25	1	2	1.28	0.45	1	1.04	-0.99
MTP	25	1	23	15.00	5.56	22	-0.97	1.10
MPT	25	10	19	15.20	2.21	9	-0.12	-0.13
MTS	25	1	14	6.40	3.67	13	0.37	-0.54

Analysis Table 4, we see that the skewness values range from -0.97 to 1.04 and the kurtosis values ranging from -0.99 to 1.10. Analyzing skewness and kurtosis, we conclude that the Gaussian curve shows no significant deviations from normality. The range (R) column shows that the standing long jump (MSD) variable has the largest range (MSD = 73.00), while the standing on one leg (MSN) variable has the smallest range (MSN = 1). Analyzing the standard deviation (Sd) and its relationship with the arithmetic mean (Mean), we find no statistically significant results.

Tabela 5. Differences in Morphological Characteristics between Handball and Volleyball Female Players

Variables	Mean Handball Females	Mean Volleyball Females	t - value	Mean Difference	p
ATV	167.42	167.44	-0.01	-0.02	0.625
ATT	56.06	56.61	-0.23	-0.55	0.003
ARR	168.00	168.31	-0.16	-0.31	0.485
ADS	18.20	18.51	-1.12	-0.30	0.852
AOS	67.28	65.32	1.14	1.96	0.005
AOK	90.20	92.04	-1.00	-1.84	0.001
BMI	19.79	20.07	-0.39	-0.27	0.001

Legend: Mean - arithmetic mean; t - t-test value; Mean Difference - mean difference values; p - significance coefficient of mean differences

Table 5 shows the results describing the average values of the morphological characteristics of handball and volleyball players, including the t-test value for each variable, the difference in means, and the p-value, representing the significance of the differences. The t-test results indicate statistically significant differences in four variables: body weight (ATT) p = 0.003, waist circumference (AOS) p = 0.005, hip circumference (AOK) p < 0.001, and BMI (p < 0.001). Other variable values are statistically insignificant. Based on the mean values, we conclude that volleyball players had higher body weight, hip circumference, and BMI, while handball players had higher waist circumference values.

Table 6 shows the t-test results indicating differences in the motor abilities of handball and volleyball players. The analysis reveals a statistically significant difference in one variable: push-ups (MTS) with p < 0.001. Other variables are statistically insignificant. Based on the mean values, handball players performed better in the push-up test, indicating stronger arm and shoulder muscles compared to volleyball players. Additionally, mean values show that volleyball players performed better in the high jump test, while handball players performed better in the standing long jump, sit and reach test, and trunk lift test. However, these differences are statistically insignificant with p > 0.05.

Tabela 6. Differences in Motor Skills between Handball and Volleyball Female Players

Variables	Mean Handball Females	Mean Volleyball Females	t - value	Mean Difference	p
MT2	3.65	3.80	-2.09	-0.14	0.262
MSV	29.20	32.04	-1.08	-2.84	0.297
MSD	178.60	174.72	0.72	3.88	0.349
MSN	1.28	1.28	0.00	0.00	1.000
MTP	6.72	15.00	-5.94	-8.28	0.511
MPT	16.96	15.20	2.76	1.76	0.958
MTS	15.84	6.40	4.17	9.44	0.001

Analyzing Tables 5 and 6, representing the t-test results of morphological characteristics and motor skills, respectively, we see statistically significant differences between the groups in the following variables: body weight (ATT), waist circumference (AOS), hip circumference (AOK), BMI, and push-ups (MTS).

Based on the mean values, handball players performed better in the standing long jump (MSD), trunk lift test (MPT), and push-ups (MTS). Additionally, handball players had lower mean values in the 20m run test compared to volleyball players, indicating that they were faster. Regarding morphological characteristics, handball players had higher waist circumference values, while volleyball players had higher values in other variables such as body height (ATV), body weight (ATT), hand length (ADS), hip circumference (AOK), arm span (ARR), and BMI. Based on the mean BMI values, both groups had optimal body weight within the range of 18.5 to 24.9 kg/m2.

Discussion

The main findings of this study indicate that there are statistically significant differences between the motor skills and morphological characteristics of young female handball and volleyball players. More precisely, handball players dominate in the standing long jump, indicating stronger leg muscles and better explosive power, which is expected given the frequent explosive changes in direction, jumping into space during goal fights and strong defensive play primarily using the legs. Volleyball players perform better in the high jump test, a movement often present in volleyball during blocking or spiking. They have learned and improved this movement well, while handball players rarely jump with both legs except occasionally when blocking a shot on goal.

Considering the findings drawn from the research and data analysis, we can observe that differences in game rules between handball and volleyball lead to differences in player performance. The young athletes in this study are still in their growth phase, and their motor skills and morphological characteristics will change over time due to training plans, programs, and other factors such as genetics, society, and lifestyle habits. These young athletes are already showing performance trends aligned with the demands of their sports. This is evident from the mean values of variables shown in Table 6, highlighting the differences in motor skills between handball and volleyball players. In this line, previous studies have also shown that handball players showed better values than volleyball players in agility tests, volleyball players showed better performances in the CMJ (counter movement jump) and CMJas (counter movement jump with arm swing) jump than handball players (Pena et al., 2016). Also, studies of Simonek et al. (2016) have shown that handball players were more successful than volleyball player in the test of maximum running speed Flying 30m sprint. In the test assessing jumping explosiveness (triple jump) the highest level of explosiveness was recorded in volleyball players.

Analyzing balance as a motor skill, tested through the standing on one leg test, both handball and volleyball players performed well, showing good balance. Regarding upper body strength, handball players demonstrated stronger arms and shoulder muscles compared to volleyball players. Conversely, volleyball players showed better flexibility in the lumbar and pelvic regions. Previous studies have shown that in the test for flexibility there was no significant difference between volleyball and handball players (Kumar, 2019). And in the test for arm strength (pull ups) there was no significant difference among the players (Dar, 2017) which is different compared to the results we obtained with this research.

In terms of morphological characteristics, differences from previous studies of older age categories are noted, which is expected since girls achieve their maximum growth rate annually between 11 and 14 years, after which growth slows down to an average of 8 cm per year. This period involves accelerated growth of limbs and hand length. Previous research (Musaiger, Ragheb, & Al-Marzooq, 1994; Bayios et al., 2006; Pena et al., 2016; Masanovic et al., 2018; Masanovic et al., 2021) showed that handball players have higher body weight while volleyball players have higher body height. In this study, the respondents had similar body height, while volleyball players had higher body weight compared to handball players.

Conclusion

This research shows that girls, even at this age, are guided by training plans and programs to develop motor skills required by their sport. Proper training helps them to progress towards the ideal model of a successful athlete. It is crucial for coaches and sports professionals working with younger categories to prioritize the proper psychophysical development of athletes over competitive results, which will naturally follow with proper and disciplined work.

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Key words: *spatial memory, blind, transfer of learning, feedback*

2.3. Main Chapters

Starting from the third page of the manuscripts, it should be the main chapters. Depending on the type of publication main manuscript chapters may vary. The general outline is: Introduction, Methods, Results, Discussion, Acknowledgements (optional), Conflict of Interest (optional), and Title, Author's Affiliations, Abstract and Key words must be in English (for both each chosen language of full paper). However, this scheme may not be suitable for reviews or publications from some areas and authors should then adjust their chapters accordingly but use the general outline as much as possible.

2.3.1. Headings

Main chapter headings: written in bold and in Title Case. *See* example:

- ✓ **Methods**

Sub-headings: written in italic and in normal sentence case. Do not put a full stop or any other sign at the end of the title. Do not create more than one level of sub-heading. *See* example:

- ✓ *Table position of the research football team*

2.3.2 Ethics

When reporting experiments on human subjects, there must be a declaration of Ethics compliance. Inclusion of a statement such as follow in Methods section will be understood by the Editor as authors' affirmation of compliance: "This study was approved in advance by [name of committee and/or its institutional sponsor]. Each participant voluntarily provided written informed consent before participating." Authors that fail to submit an Ethics statement will be asked to resubmit the manuscripts, which may delay publication.

2.3.3 Statistics reporting

JASPE encourages authors to report precise p-values. When possible, quantify findings and present them with appropriate indicators of measurement error or uncertainty (such as confidence intervals). Use normal text (i.e., non-capitalized, non-italic) for statistical term "p".

2.3.4. 'Acknowledgements' and 'Conflict of Interest' (optional)

All contributors who do not meet the criteria for authorship should be listed in the 'Acknowledgements' section. If applicable, in 'Conflict of Interest' section, authors must clearly disclose any grants, financial or material supports, or any sort of technical assistances from an institution, organization, group or an individual that might be perceived as leading to a conflict of interest.

2.4. References

References should be placed on a new page after the standard title written in upper and lower case letters, bold.

All information needed for each type of must be present as specified in guidelines. Authors are solely responsible for accuracy of each reference. Use authoritative source for information such as Web of Science, Medline, or PubMed to check the validity of citations.

2.4.1. References style

JASPE adheres to the American Psychological Association 6th Edition reference style. Check "American Psychological Association. (2009). Concise rules of APA style. American Psychological Association." to ensure the manuscripts conform to this reference style. Authors using EndNote® to organize the references must convert the citations and bibliography to plain text before submission.

2.4.2. Examples for Reference citations

One work by one author
- ✓ In one study (Reilly, 1997), soccer players
- ✓ In the study by Reilly (1997), soccer players
- ✓ In 1997, Reilly's study of soccer players

Works by two authors
- ✓ Duffield and Marino (2007) studied
- ✓ In one study (Duffield & Marino, 2007), soccer players
- ✓ In 2007, Duffield and Marino's study of soccer players

Works by three to five authors: cite all the author names the first time the reference occurs and then subsequently include only the first author followed by et al.
- ✓ First citation: Bangsbo, Iaia, and Krustrup (2008) stated that
- ✓ Subséquent citation: Bangsbo et al. (2008) stated that

Works by six or more authors: cite only the name of the first author followed by et al. and the year
- ✓ Krustrup et al. (2003) studied
- ✓ In one study (Krustrup et al., 2003), soccer players

Two or more works in the same parenthetical citation: Citation of two or more works in the same parentheses should be listed in the order they appear in the reference list (i.e., alphabetically, then chronologically)
- ✓ Several studies (Bangsbo et al., 2008; Duffield & Marino, 2007; Reilly, 1997) suggest that

2.4.3. Examples for Reference list

Journal article (print):

Nepocatych, S., Balilionis, G., & O'Neal, E. K. (2017). Analysis of dietary intake and body composition of female athletes over a competitive season. *Montenegrin Journal of Sports Science and Medicine, 6*(2), 57-65. doi: 10.26773/mjssm.2017.09.008

Duffield, R., & Marino, F. E. (2007). Effects of pre-cooling procedures on intermittent-sprint exercise performance in warm conditions. *European Journal of Applied Physiology, 100*(6), 727-735. doi: 10.1007/s00421-007-0468-x

Krustrup, P., Mohr, M., Amstrup, T., Rysgaard, T., Johansen, J., Steensberg, A., Bangsbo, J. (2003). The yo-yo intermittent recovery test: physiological response, reliability, and validity. *Medicine and Science in Sports and Exercise, 35*(4), 697-705. doi: 10.1249/01.MSS.0000058441.94520.32

Journal article (online; electronic version of print source):

Williams, R. (2016). Krishna's Neglected Responsibilities: Religious devotion and social critique in eighteenth-century North India [Electronic version]. *Modern Asian Studies, 50*(5), 1403-1440. doi:10.1017/S0026749X14000444

Journal article (online; electronic only):

Chantavanich, S. (2003, October). Recent research on human trafficking. *Kyoto Review of Southeast Asia, 4*. Retrieved November 15, 2005, from http://kyotoreview.cseas.kyoto-u.ac.jp/issue/issue3/index.html

Conference paper:

Pasadilla, G. O., & Milo, M. (2005, June 27). *Effect of liberalization on banking competition*. Paper presented at the conference on Policies to Strengthen Productivity in the Philippines, Manila, Philippines. Retrieved August 23, 2006, from http://siteresources.worldbank.org/INTPHILIPPINES/Resources/Pasadilla.pdf

Encyclopedia entry (print, with author):

Pittau, J. (1983). Meiji constitution. In *Kodansha encyclopedia of Japan* (Vol. 2, pp. 1-3). Tokyo: Kodansha.

Encyclopedia entry (online, no author):

Ethnology. (2005, July). In *The Columbia encyclopedia* (6th ed.). New York: Columbia University Press. Retrieved November 21, 2005, from http://www.bartleby.com/65/et/ethnolog.html

Thesis and dissertation:

Pyun, D. Y. (2006). *The proposed model of attitude toward advertising through sport.* Unpublished Doctoral Dissertation. Tallahassee, FL: The Florida State University.

Book:
Borg, G. (1998). *Borg's perceived exertion and pain scales*: Human kinetics.

Chapter of a book:
Kellmann, M. (2012). Chapter 31-Overtraining and recovery: Chapter taken from Routledge Handbook of Applied Sport Psychology ISBN: 978-0-203-85104-3 *Routledge Online Studies on the Olympic and Paralympic Games* (Vol. 1, pp. 292-302).

Reference to an internet source:
Agency. (2007). Water for Health: Hydration Best Practice Toolkit for Hospitals and Healthcare. Retrieved 10/29, 2013, from www.rcn.org.uk/newsevents/hydration

2.5. Tables

All tables should be included in the main manuscript file, each on a separate page right after the Reference section.

Tables should be presented as standard MS Word tables.

Number (Arabic) tables consecutively in the order of their first citation in the text.

Tables and table headings should be completely intelligible without reference to the text. Give each column a short or abbreviated heading. Authors should place explanatory matter in footnotes, not in the heading. All abbreviations appearing in a table and not considered standard must be explained in a footnote of that table. Avoid any shading or coloring in your tables and be sure that each table is cited in the text.

If you use data from another published or unpublished source, it is the authors' responsibility to obtain permission and acknowledge them fully.

2.5.1. Table heading

Table heading should be written above the table, in Title Case, and without a full stop at the end of the heading. Do not use suffix letters (e.g., Table 1a, 1b, 1c); instead, combine the related tables. *See* example:

- ✓ **Table 1.** Repeated Sprint Time Following Ingestion of Carbohydrate-Electrolyte Beverage

2.5.2. Table sub-heading

All text appearing in tables should be written beginning only with first letter of the first word in all capitals, i.e., all words for variable names, column headings etc. in tables should start with the first letter in all capitals. Avoid any formatting (e.g., bold, italic, underline) in tables.

2.5.3. Table footnotes

Table footnotes should be written below the table.

General notes explain, qualify or provide information about the table as a whole. Put explanations of abbreviations, symbols, etc. here. General notes are designated by the word *Note* (italicized) followed by a period.

- ✓ *Note.* CI: confidence interval; Con: control group; CE: carbohydrate-electrolyte group.

Specific notes explain, qualify or provide information about a particular column, row, or individual entry. To indicate specific notes, use superscript lowercase letters (e.g. [a, b, c]), and order the superscripts from left to right, top to bottom. Each table's first footnote must be the superscript [a].

- ✓ [a]One participant was diagnosed with heat illness and n = 19.[b]n =20.

Probability notes provide the reader with the results of the texts for statistical significance. Probability notes must be indicated with consecutive use of the following symbols: * † ‡ § ¶ || etc.

- ✓ *P<0.05,†p<0.01.

2.5.4. Table citation

In the text, tables should be cited as full words. *See* example:

- ✓ Table 1 (first letter in all capitals and no full stop)
- ✓ ...as shown in Tables 1 and 3. (citing more tables at once)
- ✓ ...result has shown (Tables 1-3) that... (citing more tables at once)
- ✓ ....in our results (Tables 1, 2 and 5)... (citing more tables at once)

2.6. Figures

On the last separate page of the main manuscript file, authors should place the legends of all the figures submitted separately.

All graphic materials should be of sufficient quality for print with a minimum resolution of 600 dpi. JASPE prefers TIFF, EPS and PNG formats.

If a figure has been published previously, acknowledge the original source and submit a written permission from the copyright holder to reproduce the material. Permission is required irrespective of authorship or publisher except for documents in the public domain. If photographs of people are used, either the subjects must not be identifiable or their pictures must be accompanied by written permission to use the photograph whenever possible permission for publication should be obtained.

Figures and figure legends should be completely intelligible without reference to the text.

The price of printing in color is 50 EUR per page as printed in an issue of JASPE.

2.6.1. Figure legends

Figures should not contain footnotes. All information, including explanations of abbreviations must be present in figure legends. Figure legends should be written bellow the figure, in sentence case. *See* example:

- ✓ **Figure 1.** Changes in accuracy of instep football kick measured before and after fatigued. SR – resting state, SF – state of fatigue, *p>0.01, †p>0.05.

2.6.2. Figure citation

All graphic materials should be referred to as Figures in the text. Figures are cited in the text as full words. *See* example:

- ✓ Figure 1
  - × figure 1
  - × Figure 1.
  - ✓ ….exhibit greater variance than the year before (Figure 2). Therefore…
  - ✓ ….as shown in Figures 1 and 3. (citing more figures at once)
  - ✓ ….result has shown (Figures 1-3) that... (citing more figures at once)
  - ✓ ….in our results (Figures 1, 2 and 5)... (citing more figures at once)

2.6.3. Sub-figures

If there is a figure divided in several sub-figures, each sub-figure should be marked with a small letter, starting with a, b, c etc. The letter should be marked for each subfigure in a logical and consistent way. *See* example:

- ✓ Figure 1a
- ✓ …in Figures 1a and b we can…
- ✓ …data represent (Figures 1a-d)…

2.7. Scientific Terminology

All units of measures should conform to the International System of Units (SI).

Measurements of length, height, weight, and volume should be reported in metric units (meter, kilogram, or liter) or their decimal multiples.

Decimal places in English language are separated with a full stop and not with a comma. Thousands are separated with a comma.

Percentage	Degrees	All other units of measure	Ratios	Decimal numbers
✓ 10%	✓ 10º	✓ 10 kg	✓ 12:2	✓ 0.056
× 10 %	× 10 º	× 10kg	× 12 : 2	× .056

Signs should be placed immediately preceding the relevant number.		
✓ 45±3.4	✓ p<0.01	✓ males >30 years of age
× 45 ± 3.4	× p < 0.01	× males > 30 years of age

2.8. Latin Names

Latin names of species, families etc. should be written in italics (even in titles). If you mention Latin names in your abstract they should be written in non-italic since the rest of the text in abstract is in italic. The first time the name of a species appears in the text both genus and species must be present; later on in the text it is possible to use genus abbreviations. *See* example:

- ✓ First time appearing: *musculus biceps brachii*

Abbreviated: *m. biceps brachii*

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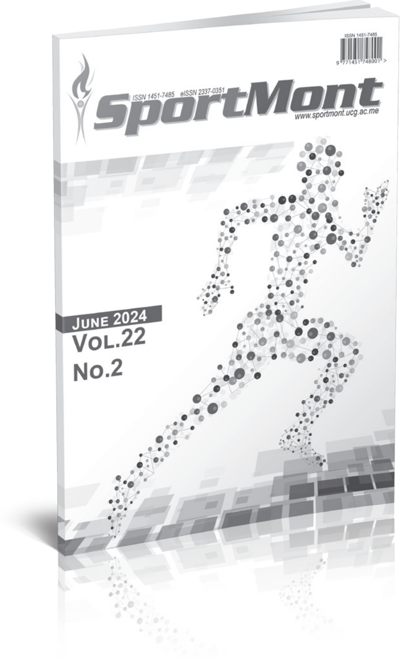

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- Community-based dialogue on articles;
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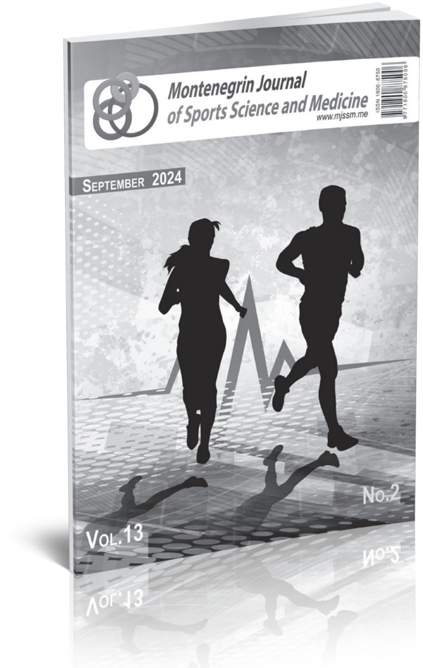
MONTENEGRIN JOURNAL OF SPORTS SCIENCE AND MEDICINE



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- Worldwide media coverage.

MJSSM is published biannually, in September and March of each year. MJSSM publishes original scientific papers, review papers, editorials, short reports, peer review - fair review, as well as invited papers and award papers in the fields of Sports Science and Medicine, as well as it can function as an open discussion forum on significant issues of current interest.

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Damir SEKULIC, Editor-in Chief – damirsekulic.mjssm@gmail.com

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MONTENEGRIN SPORTS ACADEMY

Founded in 2003 in Podgorica (Montenegro), the Montenegrin Sports Academy (MSA) is a sports scientific society dedicated to the collection, generation and dissemination of scientific knowledge at the Montenegrin level and beyond.

The Montenegrin Sports Academy (MSA) is the leading association of sports scientists at the Montenegrin level, which maintains extensive co-operation with the corresponding associations from abroad. The purpose of the MSA is the promotion of science and research, with special attention to sports science across Montenegro and beyond. Its topics include motivation, attitudes, values and responses, adaptation, performance and health aspects of people engaged in physical activity and the relation of physical activity and lifestyle to health, prevention and aging. These topics are investigated on an interdisciplinary basis and they bring together scientists from all areas of sports science, such as adapted physical activity, biochemistry, biomechanics, chronic disease and exercise, coaching and performance, doping, education, engineering and technology, environmental physiology, ethics, exercise and health, exercise, lifestyle and fitness, gender in sports, growth and development, human performance and aging, management and sports law, molecular biology and genetics, motor control and learning, muscle mechanics and neuromuscular control, muscle metabolism and hemodynamics, nutrition and exercise, overtraining, physiology, physiotherapy, rehabilitation, sports history, sports medicine, sports pedagogy, sports philosophy, sports psychology, sports sociology, training and testing.

The MSA is a non-profit organization. It supports Montenegrin institutions, such as the Ministry of Education and Sports, the Ministry of Science and the Montenegrin Olympic Committee, by offering scientific advice and assistance for carrying out coordinated national and European research projects defined by these bodies. In addition, the MSA serves as the most important Montenegrin and regional network of sports scientists from all relevant subdisciplines.

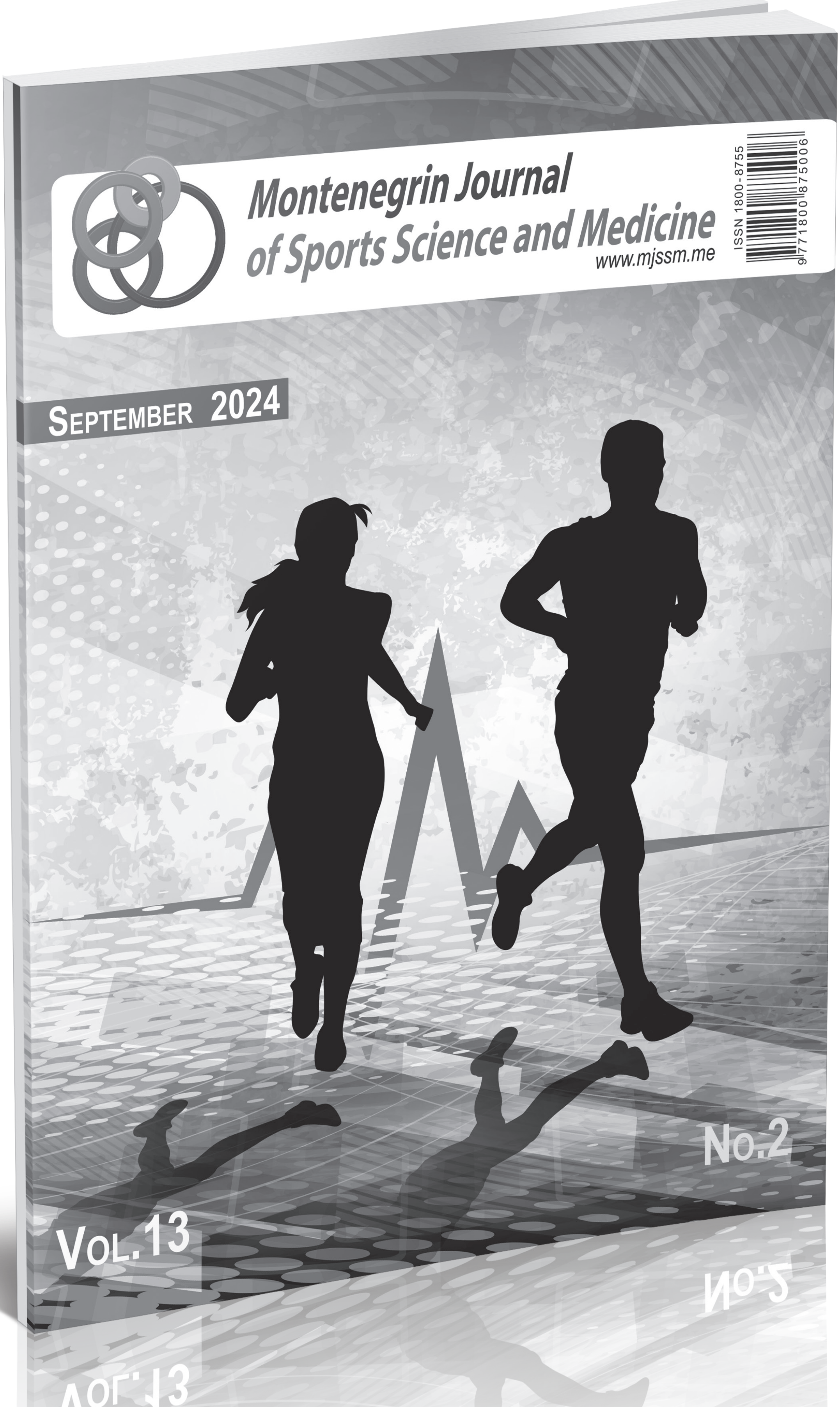
The main scientific event organized by the Montenegrin Sports Academy (MSA) is the annual conference held in the first week of April.

Annual conferences have been organized since the inauguration of the MSA in 2003. Today the MSA conference ranks among the leading sports scientific congresses in the Western Balkans. The conference comprises a range of invited lecturers, oral and poster presentations from multi- and mono-disciplinary areas, as well as various types of workshops. The MSA conference is attended by national, regional and international sports scientists with academic careers. The MSA conference now welcomes up to 200 participants from all over the world.

It is our great pleasure to announce the upcoming 21th Annual Scientific Conference of Montenegrin Sports Academy “Sport, Physical Activity and Health: Contemporary Perspectives” to be held in Dubrovnik, Croatia, from 18 to 21 April, 2024. It is planned to be once again organized by the Montenegrin Sports Academy, in cooperation with the Faculty of Sport and Physical Education, University of Montenegro and other international partner institutions (specified in the partner section).

The conference is focused on very current topics from all areas of sports science and sports medicine including physiology and sports medicine, social sciences and humanities, biomechanics and neuromuscular (see Abstract Submission page for more information).

We do believe that the topics offered to our conference participants will serve as a useful forum for the presentation of the latest research, as well as both for the theoretical and applied insight into the field of sports science and sports medicine disciplines.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