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# The effect of high-dose vitamin D supplementation and an exercise program to lose weight on some biochemical variables of overweight women

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## Abstract

### Background and Study Aim

In recent years, there has been a technological revolution and development in all fields, particularly the sports field. This has imposed on man a lifestyle characterized by comfort at the expense of a significant portion of his movement and activities. The problem of obesity has expanded beyond the inconsistency of the body to include its direct effect of increasing the proportion of fat and the negative impact on the work of vital organs. This disruption alters the body's internal environment and causes numerous diseases. The purpose of this study is to determine the effect of a sports program on taking vitamin D to lose weight and on some biochemical variables in young adults aged 30 to 35 years old.

### Material and Methods

The study involved 10 overweight women aged 30-35 years, selected through intentional sampling. Inclusion criteria required consent, good health, and no ongoing vitamin D or exercise programs. The research employed a Randomized Controlled Trial (RCT) design. Primary outcome measures encompassed body weight, body composition, lipid profile, and vitamin D status. Anthropometric measurements included age, height, weight, and training age. Biochemical measurements involved blood tests for cholesterol, triglycerides, and vitamin D levels. The experimental group received vitamin D tablets and a proposed aerobic exercise program for 12 weeks.

### Results

The proposed aerobic sports program with vitamin D intake improved biochemical variables, such as total fat, total cholesterol, triglyceride, high-density cholesterol, low-density cholesterol, OH, and Vitamin D-025 for the sample under investigation. The application of the aerobic program with vitamin D led to weight loss among the study's female participants. The aerobic program with vitamin D intake has a positive effect on the general health status of the sample.

### Conclusions

Based on the study's findings, it is recommended to consider the positive effects of Vitamin D on the overall functional state of the body, making it essential to incorporate an aerobic sports program across various age groups. Regular medical tests are crucial for monitoring and maintaining overall health. Emphasizing the importance of regular exercise is vital in preventing weight gain and reducing the risk of certain chronic diseases. By implementing these recommendations, individuals can enhance their overall well-being and lead a healthier lifestyle. To further validate these outcomes, similar studies should be conducted on different age groups and diverse samples.

### Keywords:

vitamin D, exercise, supplementation, lose weight, biochemical variables, overweight

## Terms used in the search

**Aerobic exercise:** It is the type of physical activity in which the practitioner uses large muscle groups in the body through repeated and continuous rhythmic movements while the respiratory system supplies the muscles with the needed oxygen [1].

**Obesity:** It is an aberration of the natural composition of the human body as a result of the increase in the fat percentage level [2].

**Vitamin D:** It is a group of secosteroids that dissolve directly in fat. However, it is not primarily a nutritional vitamin because the body can compensate for its deficiency through exposure to sunlight [3].

## Introduction

In recent years, there has been a technological revolution and development in all fields, particularly the sports field, which has imposed on man a lifestyle characterized by comfort at the expense of a significant portion of his movement and activities. Obesity is possibly the most prominent of these

diseases in terms of its impact on individuals and society [4].

Obesity is caused by technological advancement and lack of health education, lack of nutritional awareness, lack of exercise and physical activity, and poor eating habits. There are also factors associated with endocrine disorders or genetic and psychological factors and factors associated with poor metabolism. The issue of obesity has expanded beyond the inconsistency of the body to its direct effect of increasing the proportion of fat and the negative impact on the work of vital organs, thereby disrupting the body's internal environment and causing numerous diseases [4].

Obesity represents a deviation from the normal structure of the human body since an increase in the percentage of fat of 20% of body weight for individuals indicates the onset of obesity. The body has a natural tendency towards obesity due to the age factor until it reaches 50-70% of body weight [5]. Burt et al. [6] illustrated that the lack of physical activity leads to an increase in obesity in individuals more than an increase in the amount of food intake itself [6].

Obesity is considered a problem for a large number of individuals from a psychological perspective. Additionally, it contributes to the development of numerous chronic diseases and modern diseases, such as diabetes and various cardiovascular and circulatory diseases [5]. Carrillo [7, 8] demonstrated numerous risks of obesity, such as high cholesterol in the blood and thus the occurrence of clots, along with infertility in women, high blood pressure, diabetes, and stress due to less effort and osteoporosis.

Aerobic exercise is one of the world's most well-known healthy physical activities, particularly for obese patients. In addition, it is considered the most effective treatment for obesity because it burns calories and reduces blood cholesterol. Therefore, the practice of regulated sports activities, as mentioned by Foroozanfard et al. [9], particularly aerobic sports activities with intensity ranging between average and less than the maximum. It leads to a decrease in the percentage of blood fats of different types, especially triglycerides, whose percentage in the blood decreases temporarily after training and for 48 hours of training, thereby the continuation of the practice activities. Performing aerobic exercise (3-4) times per week can permanently maintain normal blood triglyceride levels [9].

Low-Density Lipoprotein (LDL) in the blood is known for transporting fats and depositing them on the inner walls of the arteries, causing them to narrow and causing atherosclerosis [10]. Jabbour et al. [11] reported that the practice of regulated aerobic activities according to an organized program reduces the cholesterol level in the blood, as a 1% reduction in blood cholesterol is associated with

a 2% reduction in the incidence of heart disease [12]. Physical activity a crucial role in altering the body's energy balance equation by expelling and consuming excess calories during physical activity and enhancing metabolism, thus eliminating the greatest amount of fat and preventing its storage. Physical activity also has positive effects on a number of biological factors associated with obesity and excess fat, including blood pressure, heart rate, cholesterol levels, body components, and functions of various body systems [13].

The main motive behind conducting this research is the researcher's work in the field of sports. It was noticed that many women suffer from obesity of one degree and increased cholesterol in the body and the consequent increase in weight. Moreover, the majority of women suffer from a lack of physical fitness and an increase in body fat, as well as infection with a variety of organic diseases, including diabetes, high blood pressure, atherosclerosis, and others. This prompted the researcher to develop a program of aerobic exercises, day or night, and determine the impact of this program on obesity and the levels of blood fat in women [14].

The researcher reviewed the results of the Million Health Campaign, among the results of the first phase in which the percentage of Egyptians with obesity increased [15]. Obesity is regarded as one of the primary causes and gateways to numerous diseases, such as cardiovascular disease, high blood pressure, diabetes, diseases of the musculoskeletal system and joints, as well as improper body shape, which is one of the primary reasons that obese people want to lose weight. Using a reference survey, a review of previous studies, and an international information network, the researcher determined that studies in the field of obesity did not adequately address the use of a sports diet program proposing aerobic exercises at night for obese women [1, 16].

Using a reference survey, a review of previous studies, and an international information network, the researcher found that studies in the field of obesity did not adequately address the use of a sports diet program proposing aerobic exercises at night for obese women. Consequently, the researcher conducted the current study.

#### *Importance of Research:*

- This research is among the applied research that may benefit the sports nutrition specialist.
- The inadequacy of previous studies dealing with weight loss using aerobic exercises day and night for obese women.
- This research is among the studies addressing the problems of obesity in women.

*Aim of Study.* This study aims to determine the effect of a sports program on vitamin D supplementation for weight loss and certain biochemical variables in young adults aged 30 to 35.

## Materials and Methods

### *Participants*

The research community represents a group of obese women. The research sample was chosen based on the intentional method and included 10 overweight women aged 30-35 years.

Selection criteria for the research sample:

1. Consent from the research subjects to participate in the study and aerial program.
2. The research subjects are not permitted to participate in other research.
3. The study participants have no medical conditions that prevent them from exercising, such as high blood pressure, diabetes, and liver or kidney disease.
4. Prepare for regular implementation of the proposed program and the doses of vitamin D specified before the onset of the study.

In accordance with the nature of the research, the researcher utilized the experimental method, employing the experimental design for one experimental group and implementing pre- and post-measurement.

### *Study Design*

Study Type: Randomized controlled trial (RCT)

### *Inclusion Criteria:*

- Overweight women aged 18-50 years.
- Body Mass Index (BMI) between 25 and 29.9 kg/m<sup>2</sup>.
- Generally healthy, with no known chronic diseases affecting metabolism or vitamin D absorption.
- Not currently taking vitamin D supplements or participating in a regular exercise program.

### *Exclusion Criteria:*

- Pregnant or lactating women.
- Women with a history of cardiovascular disease, renal impairment, or liver disease.
- Individuals with a known allergy or intolerance to vitamin D supplements.
- Women on medications affecting vitamin D metabolism or lipid profile.

### *Outcome Measures:*

#### *Primary Outcome Measures:*

- Body weight and body composition (e.g., BMI, waist circumference, percentage body fat)
- Body Composition:
- Total fat: Measured using techniques such as dual-energy X-ray absorptiometry (DXA) or bioelectrical impedance analysis (BIA). Reported as a percentage of total body weight or absolute fat mass.
- Lipid Profile.
- Total cholesterol: Measured using enzymatic methods. Reported in milligrams per deciliter

(mg/dL) or millimoles per liter (mmol/L).

- Triglycerides: Measured using enzymatic methods. Reported in mg/dL or mmol/L.
- High-density lipoprotein (HDL) cholesterol: Measured using enzymatic methods after precipitation of other lipoproteins. Reported in mg/dL or mmol/L.
- Low-density lipoprotein (LDL) cholesterol: Calculated using the Friedewald equation or measured directly if triglyceride levels are high. Reported in mg/dL or mmol/L.
- Vitamin D Status.
- D25 - OH - Vitamin D (25-hydroxyvitamin D): Measured using a blood sample through immunoassay methods (e.g., enzyme-linked immunosorbent assay, radioimmunoassay). Reported in nanograms per millilitre (ng/mL) or nanomoles per liter (nmol/L).

### *Research sample*

- Research community.

### *Study variables:*

- Anthropometric variables.
- Biochemical variables.

### *Methods of measuring research variables:*

#### 1- Anthropometric measurements:

- Age measurement (to the nearest month);
- Measuring the total length of the body (to the nearest 1 cm);
- Weight measurement (the closest to 100 grams);
- The training age (to the nearest month).

#### 2- Biochemical measurements:

- Cholesterol level in the blood.
- Total fat.
- High-density lipoprotein and low-density lipoprotein levels in the blood.
- The level of triglycerides in the blood.
- D25 - OH - Vitamin D.

### The measurement was carried out:

- A specialized medical team drew blood samples of 5 cm<sup>2</sup> from a vein in the upper arm after placing the compressive ligament on the ulna region. The subjects were in a sitting position on a chair with the hand extended forward in relaxation with the fist firmly clenched. After injecting the vein and drawing blood, the compressive ligament was opened.
- In the ulna area, with an open fist and draw blood.
- Each sample was transferred from the syringe to a glass tube containing heparin (an anti-coagulant) by pouring blood on the walls of the tube after removing the needle.
- The special tubes were numbered after writing the name of each player on them and placed in a special refrigerated medical bag. The samples were transferred to the laboratory to measure the biochemical variables under investigation

(cholesterol, high-density proteins, low-density triglycerides, vitamin D).

*Instruments and measurement tools:*

The researcher prepared the devices and tools necessary to carry out the measurements under study and to implement the proposed training program, which included the following:

- Plastic syringe sizes 5 cm.
- Numbered test tubes and the stand for the tubes.
- Antiseptic solution and sticky strips.
- Icebox to store blood samples.
- Digital Stopwatch to the nearest 1/100 from the second.
- Tape inserted in centimeters to measure length.
- Medical scale to measure weight.
- Pedestrian box, height 50 cm.
- Tape measure (barrel).

*The exploratory study*

The researcher conducted the exploratory study during the period from 4/1/2022 to 10/1/2022 on a sample of 10 overweight women similar to the research community and outside of the sample.

*Basic Experiment:*

Premeasurement: has been applied to the biochemical variables under study from 12/1/2022 to 15/1/2022 for all sample members under the same conditions and in the same way.

The experimental group took vitamin D tablets along with the proposed aerobic exercise program from 16/1/2022 to 17/4/2022 for 12 weeks. The training is three training times a week, orally and 3 hours before exercise, at a dose of 2 grams per day of vitamin D, equivalent to 2 tablets per day, for three months.

Post-measurement: The researcher conducted a dimensional measurement between 18/4/2022 and 19/4/2022, in accordance with what was done prior to applying for the proposed program, taking the following into account during the application:

- Measurements should be made for all members of the sample uniformly.
- The same measurement tools should be used for the entire sample.
- Measurements should be performed in the same order in which the premeasurements were taken.

*Statistical analysis*

Data analyzed using the IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp). The Kolmogorov-Smirnov was used to verify the normality of the distribution of variables. Paired t-test was used to compare two periods for normally distributed quantitative variables. ANOVA with repeated measures was used for comparing the different studied periods for normally distributed quantitative variables, followed by the post hoc test (Bonferroni adjusted) for pairwise comparison.

Pearson coefficient to correlate between two normally distributed quantitative variables. The significance of the obtained results was judged at the 5% level.

**Results**

All research subjects are homogeneous in terms of age, height, weight, and physiological and biochemical tests to ensure that they fall under the moderation curve.

**Table 1.** Distribution of demographic data and level of skewness (n = 10)

Variables	Mean	SD	Skewness
1 Age (year)	34.5	1.22	-0.128
2 Weight (kg).	93.54	4.82	0.458
3 Length (cm)	169.8	3.85	-1.002

According to Table 1, all the skewness coefficients for the research sample ranged between (-0.128 - 0.458). These values are limited to (3±), confirming the moderation of the distribution of the subjects of the research sample in the main variables of the study.

**Table 2.** Distribution of the biochemical variables of the research sample (n = 10)

Variables	Mean	SD	Skewness
Total fat (g)	372	2.99	0.299
Cholesterol (mg)	212.3	1.82	0.158
Triglycerides (mg/dL)	161.1	2.58	0.172
High-density lipoprotein cholesterol (mg/dL)	35.2	1.51	0.558
Low-density cholesterol (mg/dL)	144.4	1.35	0.438
D25 - OH - Vitamin D (nmol/L)	14.6	1.14	0.854

Table 2 shows that all the skewness coefficients for the research sample ranged between (0.158-0.854). These values are limited to (3±), confirming the moderation of the distribution of the members of the research sample in biochemical variables before conducting the study.

The study results revealed statistically significant differences in the biochemical variables between the tribal and remote measurements of the research sample in favor of the post-measurement.

Table 3 shows a statistically significant with an f-value of over 1.96 and a p-value of less than 0.05, indicating an improvement in post-measurement data.

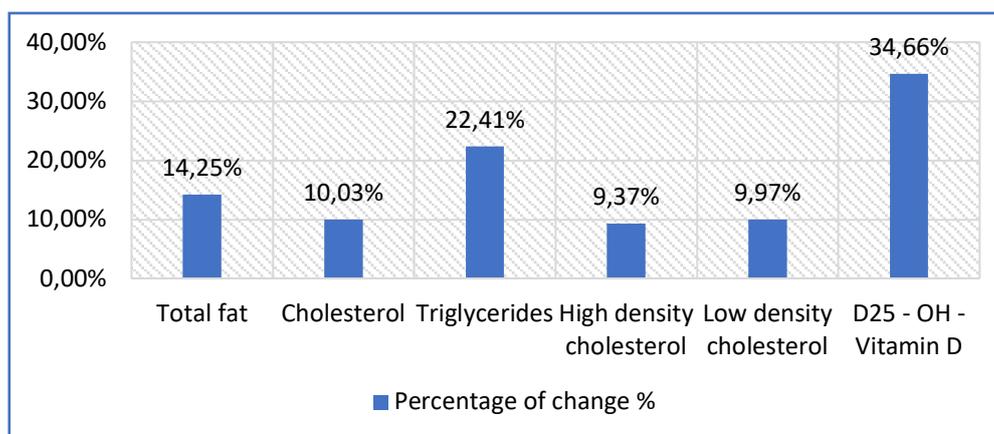
According to Figure 1, the percentage of improvement between the pre and post-measurements in the biochemical variables in the research sample. The highest percentage of variable improvement was for D25 - OH - Vitamin D (34.66%),

**Table 3.** The Relations of the pre-and post-measurements in the biochemical variables n = 10

Variables	Pre-test		Post-test		F Value	P-Value
	Mean	SD	Mean	SD		
Total fat (g)	372	2.99	319	7.96	2.852*	0.005
Cholesterol (mg)	212.3	1.82	191	7.77	2.803*	0.005
Triglycerides (mg/dL)	161.1	2.58	125	4.04	2.803*	0.005
High-density lipoprotein cholesterol (mg/dL)	35.2	1.51	38.5	0.189	2.820*	0.005
Low-density cholesterol (mg/dL)	144.4	1.35	130	4.39	2.825*	0.005
D25 - OH - Vitamin D (nmol/L)	14.6	1.14	19.66	1.63	2.844*	0.004

**Table 4.** The percentage of change between the pre-and post-measurements for the research sample in the biochemical variables n = 10

Variables	Pre-test		Post-test		The difference between averages	Percentage of change %
	Mean	SD	Mean	SD		
Total fat (g)	372	2.99	319	7.96	53	14.25%
Cholesterol (mg)	212.3	1.82	191	7.77	21.3	10.03%
Triglycerides (mg/dL)	161.1	2.58	125	4.04	36.1	22.41%
High-density lipoprotein cholesterol (mg/dL)	35.2	1.51	38.5	0.189	3.3	9.37%
Low-density cholesterol (mg/dL)	144.4	1.35	130	4.39	14.4	9.97%
D25 - OH - Vitamin D (nmol/L)	14.6	1.14	19.66	1.63	5.06	34.66%



**Figure 1.** The percentage of change between the pre and post measurements

while the lowest percentage of improvement was for the High-density cholesterol variable (9.37%).

## Discussion

The results of Table 3 and Figure 1 revealed statistically significant differences between the pre-and post-measurements at the significance level of 0.05. The percentage of improvement for all biochemical variables under study ranged from 9.37% to 34.6% in favor of the dimensional measurement. This improvement in biochemical variables can be attributed to the vitamin D intake sports program due to the diversity of the exercises used for 12 weeks and the regularity of all sample members. This had a significant impact on improving biochemical variables, and metered

doses of vitamin D contributed to raising vitamin D levels. Some evidence suggests that getting enough of this vitamin can promote weight loss and reduce body fat, thereby aiding in weight loss.

Sepehrmanesh [17] illustrated that the practice of aerobic physical activity increases the metabolic rate in the body. This activity aids in burning fats and dissolving fats accumulated in fat cells, thus encouraging the body to use fats as energy and increasing the level of good cholesterol [17]. Studies revealed that vitamin D could reduce the formation of new fat cells in the body and prevent the storage of fat cells, effectively reducing fat accumulation. Vitamin D can increase serotonin levels, affecting mood and sleep regulation [2].

Serotonin may play a role in appetite

control, increased satiety, weight loss, and decreased calories burned. Increased vitamin A levels may also be associated with increased testosterone levels, promoting weight loss [18]. At a significance level of 0.05, the results of Table 3 indicate that the concentration of triglycerides decreased significantly between the pre-and post-measurements. The percent of improvement in triglyceride concentration was 22.41. This result can be attributable to the effect of aerobic training and vitamin D supplementation, which reduces the level of triglyceride concentration until it reaches a plateau that can be maintained with physical exercise.

According to Wagner et al. [19], the aerobic energy system depends on glycogen and fats as indirect sources of energy production, with aerobic training helping to balance the representation of fat in the body via muscle cells, allowing it to be deposited in fat cells or eliminated by the liver [19]. The results also indicated statistically significant differences in total cholesterol concentration, HDL, and LDL. As the level of total cholesterol concentration decreased and the percentage of improvement reached 10.03 %, the level of HDL increased, and the percentage of improvement reached 9.37 %. Moreover, the level of LDL cholesterol concentration decreased, and the percentage of improvement reached 9.97%. This result is due to the effect of the proposed training program with its aerobic exercises and the regularity of the sample members during its application.

According to Wamberg et al. [20], regular physical activity has a significant impact on the ratio of total cholesterol, high-density lipoprotein cholesterol, and low-density lipoprotein cholesterol (LDL) [20]. The significance of a low LDL cholesterol concentration suggests that it is the leading cause of coronary artery disease and that there is a direct correlation between the level of LDL cholesterol and physical fitness; the higher the concentration of LDL cholesterol, the lower the level of physical efficiency [21].

Therefore, the first hypothesis, which states that “there are statistically significant differences between the pre and post-measurements between the research sample in the biochemical variables in favor of the post-measurement,” has been confirmed.

#### *Superiority of Research*

**Novel Intervention Approach:** Our study stands out by examining the synergistic effects of high-dose vitamin D supplementation and an exercise program in overweight women. While previous studies have separately investigated these interventions, the combined effects remain relatively unexplored. By integrating both interventions, we expect to observe additive or potentially synergistic effects on biochemical variables, leading to improved weight

loss and metabolic outcomes.

**Rigorous Study Design:** Our research utilizes a randomized controlled trial (RCT) design, the gold standard for studying intervention effects. This design allows for robust comparison and minimizes bias, enhancing the validity and reliability of our findings. Furthermore, blinding researchers and participants to intervention assignments reduces potential biases, ensuring a high-quality study.

**Comprehensive Outcome Measures:** Our study focuses on multiple biochemical variables, including body composition (total fat), lipid profile (total cholesterol, triglycerides, HDL cholesterol, LDL cholesterol), and vitamin D status (D25 - OH - Vitamin D). By assessing a wide range of relevant variables, we can provide a comprehensive understanding of the impacts of the intervention on metabolic health markers in overweight women.

#### *Novelty of Research*

**Targeted Population:** Our study specifically targets overweight women, a population at increased risk of developing metabolic disorders. By focusing on this demographic, we address a critical research gap and provide insights into tailored interventions for weight management and metabolic health in this vulnerable group.

**High-dose Vitamin D Supplementation:** While the effects of standard or low-dose vitamin D supplementation have been investigated to some extent, our study explores the impact of high-dose vitamin D supplementation on biochemical variables. This higher dosage may elicit more substantial effects on weight loss and metabolic parameters, potentially uncovering novel findings and contributing to the existing literature on vitamin D supplementation.

**Integration of Exercise Program:** Our research combines high-dose vitamin D supplementation with an exercise program, acknowledging the interplay between nutrition, supplementation, and physical activity in weight management. This integration is novel in overweight women, allowing us to explore the potential synergistic effects of these interventions on biochemical variables.

## **Conclusion**

Considering the objectives of the research and presenting the results within the limits of the research sample, the following can be concluded:

1. The proposed aerobic sports program with vitamin D intake led to an improvement in biochemical variables, including total fat, total cholesterol, triglyceride, high-density cholesterol, low-density cholesterol, OH, and vitamin D - 025) for the sample under investigation.
2. The application of the aerobic program with vitamin D resulted in weight loss among the

study's female participants.

3. The aerobic program with vitamin D intake has a positive effect on the general health status of a sample.

## Recommendations

Within the limits of the research community and according to the findings, the researcher recommends the following.

1. Vitamin D has a positive effect on the general

functional state of the body, necessitating the implementation of an aerobic sports program at various ages.

2. Similar studies should be performed on different age groups and samples.
3. Medical tests should be conducted periodically to follow up on the health status of the body.
4. There should be a focus on regular exercise to prevent weight gain and certain chronic diseases.

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# Physiological parameters of professional football players in teams of various levels

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

## Abstract

**Background and Study Aim** Soccer is a demanding sport which, in addition to technical and motor characteristics, also requires exceptional functional abilities of athletes to play at a high level. The aim of this study: 1) To analyze the disparities in physiological parameters among professional soccer players in teams of varying levels. 2) To explore potential connections between team ranking positions and the physiological attributes of professional soccer players.

**Material and Methods** 91 professional soccer players who compete in Serbian Super league (age 24.14±5.15) were included in the study. Participants were classified into two groups. The first group consisted of players from teams that were ranked from third to sixth place at the end of 2021/2022 competitive season (n=49). The second group of participants consisted of the players of the teams that were ranked in the last two places at the end of the above-mentioned season (n=42). Maximal oxygen consumption (VO<sub>2</sub>max), as well as running speeds and heart rates at first and second ventilatory thresholds (VT1 and VT2) were obtained by performing maximal cardiopulmonary exercise test.

**Results** The results showed a statistically significant difference in terms of VO<sub>2</sub>max values, running speeds and heart rates at VT1 and VT2 when the top and bottom ranked teams were compared (p < 0.001).

**Conclusions** The results of the study imply that playing high-level soccer requires exceptional functional abilities, which go beyond technical and tactical characteristics. These exceptional abilities enable players to continuously perform at high intensities during the games in order to achieve top results. Coaches should be aware of the importance of high aerobic capacity for achieving top results, especially if the team consists of less talented players.

**Keywords:** functional abilities, competitive rank, soccer, training thresholds

## Glossary:

VO<sub>2</sub>max – maximal oxygen consumption;

VT1 – first ventilatory threshold;

VT2 – second ventilatory threshold;

HR at VT1 – heart rate at first ventilatory threshold;

HR at VT2 – heart rate at second ventilatory threshold;

V at VT1 – running speed (km/h) at first ventilatory threshold;

V at VT2 – running speed (km/h) at second ventilatory threshold.

## Introduction

Soccer is an intense and physically demanding sport that is characterized by cyclic and acyclic movements, and apart from the technical, tactical, and motor characteristics of athletes, this sport also requires high aerobic and anaerobic endurance [1]. Soccer is primarily an anaerobic sport due to high intensity sprint sections performed in solving technical and tactical tasks in attack and defense. On the other hand, aerobic capacity ensures continuity in the implementation of these high-

intensity anaerobic sections, as well as fast recovery after them.

Aerobic capacity represents the organism's ability to create energy for physical work through aerobic processes [2, 3]. The measure of aerobic capacity is maximal oxygen consumption (VO<sub>2</sub>max) which, according to most authors, is the best indicator of athletes' cardiorespiratory fitness [4, 5]. Expected VO<sub>2</sub>max values for professional soccer players range from 55 to 70 mL/kg/min [6, 7]. High VO<sub>2</sub>max values enable training at a higher intensity while using oxygen to generate energy, which means reaching the first and second ventilatory thresholds (VT1 and VT2) at higher heart rates and delaying anaerobic fatigue.

The ventilatory (or anaerobic) thresholds represent the moment of increase in lactate and lactate/pyruvate ratio in muscles and arterial blood and occurs at that level of physical activity above which, in addition to the generation of energy in aerobic conditions, the energy is also produced during anaerobic metabolic processes, such as anaerobic glycolysis [8]. In different literature and by different authors, these thresholds are also called "first and second lactate thresholds",

“anaerobic thresholds” or „aerobic and anaerobic thresholds” [9]. For this study purposes we use terms first and second ventilatory thresholds since the ergospirometry was performed to obtain these parameters.

Certain research shows that achieved work intensity at VT1 and VT2, in terms of obtained heart rates at these thresholds, is a better indicator of cardiorespiratory fitness in soccer players than  $VO_2$ max value itself [4]. In other words, the higher the running speed and heart rate at VT1 and VT2, the better the aerobic efficiency and endurance of an athlete [10]. The intensity of effort at which VT1 and VT2 are obtained can be improved by specific training sessions even without raising the  $VO_2$ max values and this is, according to some authors, much more important for performance of soccer players [11, 12, 13].

Determination of ventilatory thresholds and  $VO_2$ max is performed with a cardiopulmonary exercise test (CPET) by monitoring direct gas exchange (oxygen and carbon dioxide) [14, 15]. The first threshold is defined as the first increase of lactate in the blood, followed by an immediate increase of ventilation needed to deliver oxygen ( $O_2$ ) to the cells, and export carbon dioxide ( $CO_2$ ) to the outside environment. The second threshold is called the respiratory compensation point because above this threshold the work is performed in 100% anaerobic conditions, and hyperventilation is the only compensatory mechanism by which the body tries to prevent ongoing metabolic acidosis [16].

Previous research shows that the first rise in blood lactate (reaching the first ventilatory threshold) in professional soccer players occurs at average treadmill running speeds of 12.3 km/h (VT1 = 2 mmol/L of blood lactate), while second pronounced rise in blood lactate (second ventilatory threshold) is reached at speeds higher than 15 km/h (VT2 = 4–6 mmol/L of blood lactate) [17]. Heart rates obtained during CPET at first and second ventilatory thresholds are extremely important for adequate dosage of training, which ensures the achievement of supercompensation and positive training effects [18].

*Hypothesis.* Hypothesis suggests that significant differences in physiological parameters, including oxygen consumption, heart rates, and running speeds, will be observable among professional soccer players based on the ranking positions of their respective teams.

*The aim of the study:* 1) To analyze the disparities in physiological parameters among professional soccer players in teams of varying levels. 2) To explore potential connections between team ranking positions and the physiological attributes of professional soccer players.

## Material and Methods

### *Participants*

For the purposes of this research, the sample of participants consisted of 91 senior professional soccer players from five different Serbian teams (age  $24.14 \pm 5.15$ , height  $181.84 \pm 6.11$  cm, weight  $75.69 \pm 6.62$  kg). They were classified into two study groups. The first group was made up of players from 3 different soccer teams ( $n=49$ ) which were ranked from third to sixth place at the end of competitive season. The participants from the second study group were players who played for two soccer teams which ended up in the last two places at the end of 2021/2022 Serbian Super league. The criteria for inclusion in the study were players age  $\geq 18$  to  $\leq 35$  years, training age  $\geq 6$  years, without recent injury ( $> 12$  months). Cardiopulmonary exercise testing was conducted at the beginning of the macrocycle, as a part of pre-participation medical screening, and before the start of the competitive season. Each participant voluntarily provided written informed consent before participating in the study and performing the CPET. The conducted research does not violate the rights of the examined players, according to the ethical standards of the Helsinki Declaration of the Committee on Human Rights (WMA Declaration of Helsinki, 2013). The Research Ethics Committee for human test subjects of Sports Cardiology Association of Serbia approved all study procedures.

### *Procedures*

The sample of variables used in the research represent the parameters of morphological and functional abilities of soccer players. Determination of body height was done using a Seca altimeter (unit of measure is 1 cm). The Tanita® BC-418MA scale (bioimpedance method) was used to determine body weight (kg), BMI ( $kg/m^2$ ), and FAT%. An electrocardiogram of the heart at rest was performed using a 12-channel ECG (Fukuda®). To implement CPET, a treadmill (HP-COSMOS®) was used, while  $VO_2$ max, as a measure of aerobic capacity, and heart rates and running speeds at VT1 and VT2, were determined by using the Quark CPET system (Cosmed®) while direct monitoring of gas exchange ( $O_2$  and  $CO_2$ ). A protocol for professional soccer players was used to perform the test, with an initial speed of 6 km/h and an elevation of 3°. The treadmill running speed was increased by 1 km/h every 40 seconds until the player had reached volitional exhaustion, as well as maximal heart rate is achieved (at least 90% of maximal heart rate in theory according to formula  $220 - \text{age}$ ), plateau in oxygen consumption is obtained and respiratory quotient is above 1.10. Heart rate was continuously monitored with a short-range telemetry HR monitor and 12-lead Stress ECG.

Determination of first and second ventilatory thresholds (VT1 and VT2) were obtained during CPET by using Wasserman 9-Panel Plot and Omnia software. The VT1 and VT2 are usually obtained by analyzing all Wasserman panels, with particular attention to  $VO_2$  vs.  $VCO_2$  (*V-slope* method), ventilatory equivalents for  $O_2$  and  $CO_2$  ( $VE/VO_2$ ;  $VE/VCO_2$ ), respiratory quotient ( $RQ = CO_2/O_2$ ), and  $PetO_2$  and  $PetCO_2$  panels. The VT1 was determined according to different validated methods: modified *V-slope* method, ventilatory equivalent method ( $VE/VO_2$  panel), and end tidal  $O_2$  pressure method ( $PetO_2$  panel). The VT2 was determined by using the ventilatory equivalent method ( $VE/VCO_2$  panel), at the point where ventilation (VE) increases out of proportion to  $VCO_2$  and RQ is  $\geq 1$  and end tidal  $PetCO_2$  method ( $PetCO_2$  panel) [19].

#### Statistical analysis

To describe parameters of importance, depending on their nature, the following were used: frequency, percentages, sample mean value, sample median, sample standard deviation, rank and 95%

confidence intervals. The Shapiro Wilk tests were used, to test the normality of the distribution, as well as the graphs: histogram and normal QQ plot. To test the differences in maximal oxygen consumption, running speed and heart rates at ventilatory thresholds between the study groups of soccer players the Independent simple T test with Levene's Test for Equality of Variances was used, as well as Mann Whitney U test. Statistical data processing was performed in the statistical package SPSS 20.0 for Windows. Differences were considered significant when the p value was less than 0.05.

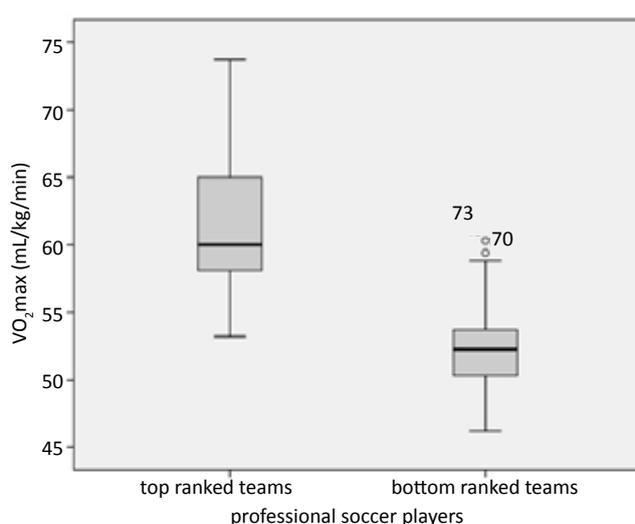
## Results

A comparative statistic of measured variables which represent functional abilities (cardiorespiratory fitness) of soccer players is shown in Table 1. In the field of functional abilities, a statistically significant difference ( $p < 0.001$ ) was observed in terms of  $VO_{2max}$  values (Figure 1), and heart rates at VT1 and VT2, respectively (Figure 2 and Figure 3). Furthermore, a statistically significant

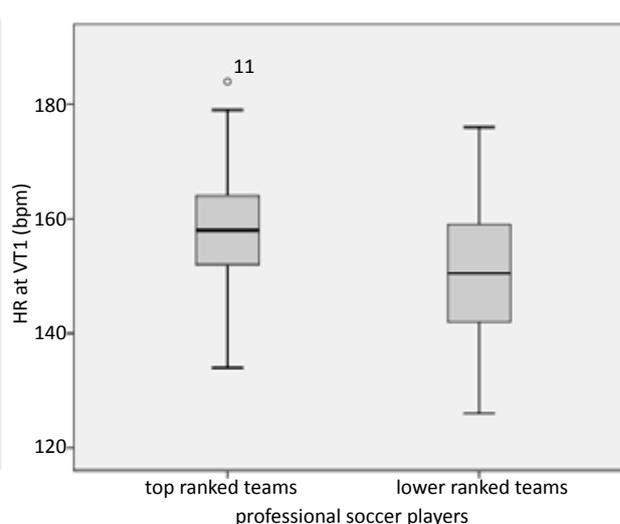
**Table 1.** A comparative statistic of functional abilities of soccer players from top and bottom ranked teams.

Variables	Top ranked teams	Bottom ranked teams	t value	p value
	$\bar{X} \pm SD$	$\bar{X} \pm SD$		
N° of participants	49	42		
$VO_{2max}$ (mL/kg/min)	61.37±5.07	54.57±5.96	10.109	0.000
HR at VT1 (bpm)	157.49±11.21	150.52±12.06	3.469	0.001
HR at VT2 (bpm)	176.18±10.27	170.76±8.04	3.510	0.001
V at VT1 (km/h)	12.53±1.52	9.57±1.57	11.020	0.000
V at VT2 (km/h)	16.41±1.91	12.83±1.87	11.212	0.000

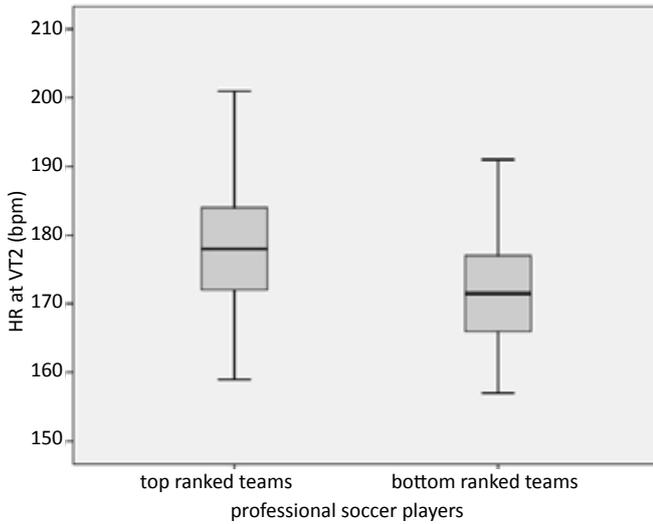
*Abbreviations:*  $VO_{2max}$  (maximal oxygen consumption); HR (heart rate); HR at VT1 (heart rate at first ventilatory threshold); HR at VT2 (heart rate at second ventilatory threshold); V (running speed).



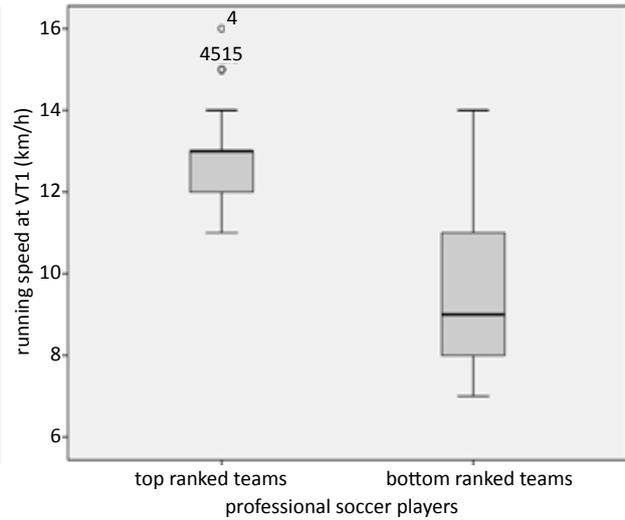
**Figure 1.** Distribution of  $VO_{2max}$  values within different ranked soccer teams at the end of the competitive season.



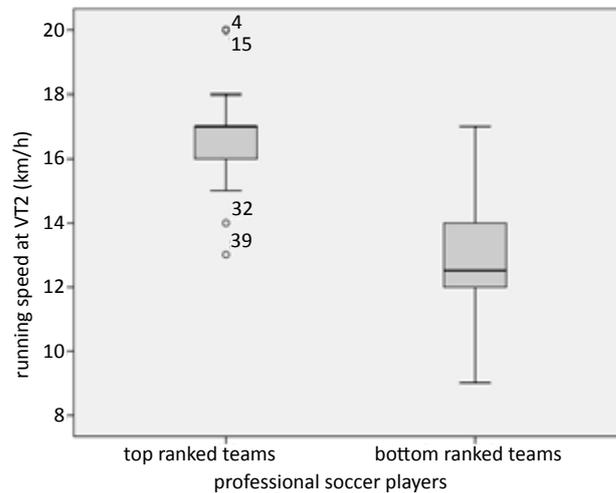
**Figure 2.** Distribution of HR values at VT1 within different ranked soccer teams at the end of the competitive season.



**Figure 3.** Distribution of HR values at VT2 within different ranked soccer teams at the end of competitive season.



**Figure 4.** Distribution of running speed values at VT1 within different ranked soccer teams at the end of competitive season.



**Figure 5.** Distribution of running speed values at VT2 within different ranked soccer teams at the end of competitive season.

difference ( $p < 0.001$ ) was also found in running speed at VT1 and VT2 (Figure 4 and Figure 5).

## Discussion

### *Aerobic capacity*

The results of our study showed that functional abilities (cardiorespiratory fitness) are very important for playing top level soccer, which agrees with previous research on this topic [1, 6, 9]. Primary findings of this research support the fact that players from the top ranked teams, during competitive season, had statistically better results in terms of all functional (cardiorespiratory) parameters compared to soccer athletes from bottom ranked teams. Although evaluated athletes played in the same level of competition, where the physical demands of the sport are equal, the difference in  $VO_2\max$  values was obvious, which could explain the differences in ranking during and at the end

of the competition. The study showed that players from top ranked teams had a statistically much better aerobic capacity ( $VO_2\max$  61.37 mL/kg/min vs. 54.37 mL/kg/min) than players from the bottom ranked teams. Soccer players from lower ranked teams had similar aerobic abilities as professional basketball players from the EuroLeague basketball competition [20], even though it is expected for soccer players to obtain much higher  $VO_2\max$  values than senior basketball players. At the same time, the results of maximal oxygen consumption obtained by top ranked players were within the values for the sports discipline, described in earlier studies [21, 22, 23]. Furthermore, considering aerobic capacity, soccer players from Serbian top ranked teams achieved higher  $VO_2\max$  values than professional soccer players from Croatia, Brazil and Greece [24, 25, 26]. Comparing the aerobic capacity of bottom ranked teams from our research, a lower oxygen consumption values are obtained compared to semi-

professional soccer players of the 3<sup>rd</sup> and 4<sup>th</sup> League from Italy, which could also explain low ranking at the end of the season [27].

#### *Running speed at ventilatory thresholds*

In terms of running speed at ventilatory thresholds a statistically significant difference ( $p < 0.001$ ) was obtained comparing soccer players from the top and bottom ranked teams. Soccer athletes from the top ranked teams were reaching the first and second ventilatory threshold at much higher running speeds, which means that they were using oxygen for energy production much longer during the effort and were postponing absolute anaerobic metabolic onset and fatigue. These results could be explained by the fact that top ranked teams are usually playing certain qualifying matches for different European competitions, and therefore they must be prepared to compete at a higher level of intensity in those matches. Compared to other studies, the Serbian soccer players from the top ranked teams were reaching ventilatory thresholds at higher running speeds [15, 26], but compared to elite football players from Croatia, the average running speeds at ventilatory thresholds were the same [24]. At the same time, soccer players from the lower ranked teams were achieving anaerobic fatigue much faster and at lower running speeds, and these results are weaker compared to the soccer players from other countries [28].

#### *Heart rate response on ventilatory thresholds*

Considering heart rate values at the first and second ventilatory thresholds a statistically significant difference was observed between the two study groups of players. Athletes who played for top ranked teams were reaching ventilatory thresholds at much higher heart rates. This means that they were able to perform physical activity in aerobic conditions at much higher effort intensity compared to players from low ranked teams. Oxygen, as a substrate for the creation of adenosine triphosphate, was used significantly longer and at a higher intensity during CPET, which is a good indicator of a great cardiorespiratory fitness [5, 6]. These results could explain better ranking position at the end of competition since high level of aerobic capacity and efficiency, with prolonged utilization of oxygen during matches makes it possible to perform anaerobic tasks in soccer during the entire 90 minutes of the game at the same intensity level [16].

The obtained results of the study showed that the achieved heart rate values at the second ventilatory threshold match the results obtained with Greek soccer players [15, 26]. At the same time, Serbian soccer players who played for top ranked teams were achieving second ventilatory threshold much earlier

(at lower heart rates) compared to soccer players from Brazil and Croatia, which could generally explain the better results of these countries on the world soccer scene compared to Serbia [9, 29, 30].

The limits of this study are the tests performed only before the beginning of the competitive season, and it is not known how and with what intensity the players from both groups trained during the one-year competitive macrocycle. The implications for further research should address the importance of regular functional screening of soccer players (pre-season, after pre-season training camps, half-season, and at the end of the competitive season) to follow changes in functional capacity of athletes, which enables adequate training corrections with the aim of improving sports results.

## **Conclusion**

The research rejected the H<sup>0</sup> hypothesis which stated that there would be no difference between the two study groups in terms of functional abilities. The results of the study confirmed the H<sup>1</sup> hypothesis and statistically significant difference in terms of VO<sub>2</sub>max values and heart rates, as well as, running speeds achieved at first and second ventilatory thresholds. Professional soccer players who played for top ranked teams in Serbian Super league had better aerobic both capacity and economy. Furthermore, these players were able to postpone the onset of absolute anaerobic metabolic pathways for producing energy for work, which can explain better ranking at the end of competitive season, since they could utilize O<sub>2</sub> much longer and more efficient compared to players from bottom ranked teams. This means that VO<sub>2</sub>max is not the only value important for sports success, but also the intensity of effort at which ventilatory thresholds are reached. Very often, a lack of talent, as well as technical and tactical elements of a sport can be compensated by adequately developed cardiorespiratory fitness. Considering this fact, the practical application of this research could lead to the implementation of specific training by soccer teams (especially bottom ranked ones) with the aim of increasing the VO<sub>2</sub>max values and both heart rates and running speeds at which ventilatory thresholds are reached during the effort.

## **Acknowledgement**

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## **Conflicts of Interest**

The authors declare no conflict of interest.

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## Static vs dynamic stretching: which is better for flexibility in terms of gender of badminton athletes?

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### Abstract

**Background and Study Aim** Flexibility is a crucial component of physical conditioning for badminton players. In this context, this study aims to investigate the impact of static and dynamic stretching on the flexibility of badminton athletes. The research objectives include analyzing the effectiveness of each stretching technique, comparing flexibility between male and female players, and examining the interaction between stretching methods and gender on athletes' flexibility.

**Material and Methods** This type of research is an experiment using a 2x2 factorial design. The participants were 20 badminton athletes aged 14-16 years. The sample obtained 10 male athletes and 10 female athletes. The flexibility instrument uses the sit and reach test. The data analysis technique used is ANOVA two way.

**Results** Static stretching demonstrated greater effectiveness than dynamic stretching on flexibility (p-value  $0.033 < 0.05$ ). A notable difference was observed between male and female athletes regarding flexibility, with females exhibiting better flexibility (p-value  $0.004 < 0.05$ ). The study identified a significant interaction between stretching techniques (static and dynamic) and gender (male and female) on flexibility (p-value  $0.000 < 0.05$ ).

**Conclusions** The research findings highlight the importance of gender-specific training programs that consider individual muscle capabilities and characteristics. By tailoring training regimens to each gender, badminton athletes can enhance their performance and reduce the risk of injuries. Based on these findings, it is recommended that badminton coaches and practitioners take into account the observed differences in the effectiveness of static and dynamic stretching based on gender.

**Keywords:** stretching static, stretching dynamic, flexibility, gender

### Introduction

Badminton is a sport that belongs to the group of game sports. Badminton games can be played on or off the court, with the court being demarcated by lines of a certain length and width [1]. The badminton game uses a racket as a batting tool and a shuttlecock as the object being hit, the playing field is rectangular and is limited by a net to separate the playing area itself and the opponent's playing area [2]. Badminton sport is popular because almost every area is found badminton courts in both indoor and outdoor forms. The physical condition factor of athletes is very important in supporting the implementation of technical and tactical training. All sports, including badminton, definitely require good physical condition. Good physical condition can optimize in training and in a match. Physical condition is a capacity that must be possessed by an athlete in improving and developing maximum sports achievement. Some components in badminton physical condition are muscular power, explosive power, speed, coordination, endurance,

reaction, strength, accuracy, flexibility, agility, and balance [3, 4, 5].

One of the physical condition elements needed for badminton players is flexibility [6, 7]. Flexibility is the ability of a joint to move with full Range of Motion (ROM), easily, without resistance and pain. An individual's ability to move smoothly depends on their flexibility, an attribute that enhances safety and optimizes physical activity. Flexibility is the ability of a joint, its surrounding muscles and ligaments to move freely and comfortably within the maximum expected range of motion. Flexibility is the ability of a joint to move within its joint range of motion [8,9]. Badminton players need a high level of flexibility to handle movements that are difficult to reach. Flexibility can affect the results of smash shots, where the flexibility of the backward took when doing smash will increase the strength of the blow. The better the backward bending of an athlete, the better the basic techniques that the athlete has, especially the basic smash technique. Research results showed that there is a significant relationship between flexibility and badminton smash ability [10]. Research results shows that there is a significant relationship between wrist flexibility and badminton service ability [11].

Based on the results of observations in February 2023, it shows that the players' flexibility is still low. Like players when doing smash and service techniques, the flexibility of the wrist is too stiff, so that when hitting the shuttlecock the results are not good. Flexibility is one of the variables that support the results of smash ability. Flexibility can help swing the waist when hitting a smash, so that the shuttlecock hit is precise, strong and sharp at the target that the athlete has determined. Therefore flexibility also has an important role in smash ability.

It should be noted that choosing an exercise method to help smooth the training process is one of the very strategic efforts that can be made by a coach to deliver the training material that has been prepared. This is so that the training process is more interesting and fun, so that the training objectives can be achieved. The results of the methods provided by coaches that are less varied result in athletes not being able to improve mastery and understanding of the concept of motion optimally. This flexibility is needed by every athlete to make it easy to learn various movements, improve skills, reduce the risk of injury, and optimize strength, speed, and coordination. Determination can be developed through stretching exercises [stretching], whose model consists of dynamic stretch, static stretch, passive stretch, and Proprioceptive Neuromuscular Facilitation (PNF) [12,13].

The method that will be applied is the static stretching exercise method and the dynamic warm-up exercise method. Through stretching movements (stretching) can increase the range of motion (ROM) of the joints [14]. Stretching can improve flexibility, stamina, muscle strength, reduce joint muscle pain, have a greater ability to move maximum force through a wide range of motion, prevent some lower back problems, improve appearance and self-image and improve body alignment and posture [15]. Revealed that static and dynamic stretching are two commonly recommended stretching techniques to improve flexibility [16]. The right series of stretching exercises for flexibility should follow the general principles of training, namely: readiness, specificity, regularity, frequency, adjustment, overload, and size.

Static stretching is a type of stretching exercise in which muscle lengthening is performed with low force and long duration (usually 30 seconds). Static stretching has a relaxing effect, a lengthening effect on the muscle, increases range of motion, reduces muscle stiffness and also reduces the risk of acute muscle injury [17]. Static stretching is a movement that is performed slowly on the muscles until tension occurs and pain is reached. Stretching with this technique the body position is maintained without moving. Static stretching is a stretching exercise performed by maintaining the position of the stretched muscle for a long time, this stretch is done slowly and smoothly. When the muscle is

stretched, the muscle spindle will also be stretched. Muscle spindles will report changes in length and how fast changes in muscle length occur, muscle spindles will also provide signals to the spinal cord to forward information to the central nervous system [18]. One of the advantages of static stretching is that it facilitates the Golgi Tendon Organ (GTO). Static stretching performed on the muscle tendon unit has been known to activate the GTO. Static stretching has been shown to be very effective in increasing hamstring length [19].

Dynamic stretching exercise is a stretching exercise by moving the body or limbs rhythmically without maintaining the farthest stretch position [20]. Dynamic stretching is a traditional training method to train flexibility, which is stretching done by moving the body or limbs rhythmically with rotating or bouncing movements of the limbs in such a way that the muscles feel stretched. The advantage of dynamic stretching exercises is that they progressively increase joint motion space, while the disadvantage of dynamic stretching exercises is that they can cause pain and injury to the muscles [21]. Exercises performed with regular frequency such as dynamic stretching exercises performed regularly for six days are physical activities that use the long term energy system [22]. Exercise that uses a long term energy system and is carried out continuously will cause adaptation to the mitochondria, so that energy metabolism is better. Aerobic metabolism increases the effectiveness of the level of muscle work making the oxygen supply sufficient to produce more energy and increase the peripheral response which causes vasodilation of the blood vessel walls and causes blood flow to be smooth, so that the heart workload decreases and so the pulse rate decreases. The decrease in pulse rate is caused by the frequency of exercise, namely dynamic stretching exercises which are carried out regularly for six days, and the results are known to be quite significant. Exercise frequency is closely related to exercise intensity and exercise duration. In doing exercise, the frequency of exercise should be carried out at least three times a week, both for health sports and for sports achievements. In this context, this study aims to investigate the impact of static and dynamic stretching on the flexibility of badminton athletes. The research objectives include analyzing the effectiveness of each stretching technique, comparing flexibility between male and female players, and examining the interaction between stretching methods and gender on athletes' flexibility.

## Materials and Methods

### *Participants*

The participants in this study were PB. MDP Sleman badminton athletes totaling 58 athletes. The sampling technique used is purposive sampling. The

criteria are still actively training, male and female, aged 14-16 years, not in pain, willing to follow the rules in the treatment applied. Based on these criteria, there were 20 athletes who met. The sample obtained 10 male athletes and 10 female athletes. Then from each of these data is divided into two groups by means of ordinal pairing and obtained 5 male athletes each were given static stretching exercises and 5 people were given dynamic stretching exercises, the same was done for groups of female athletes.

*Research Design*

This type of research is an experiment using a 2x2 factorial design (Table 1). Factorial design is experimental designs with more than one independent variable (manipulated) are known as factorial experimental designs. The term factor refers to each independent variable that is manipulated. The following is the research design for this experimental research.

Flexibility is assessed using a sit-and-reach test. This is done at the gym using standard boxes. Participants sit on the floor with their feet extended to most of their knees with the soles of their bare feet placed in a prone box. Participants are asked to reach the chest measurement line as far as possible and hold this position for 1-3 seconds. Participants were tested three times with the best result recorded in centimetres [23]. Static and dynamic stretching exercises were performed for 18 meetings.

*Statistical Analysis*

Data analysis can also be defined as an activity carried out to convert data from research into new information that can be used in making conclusions.

The data analysis technique used in this study using Statistical Package for the Social Sciences (SPSS) software, specifically version 21. SPSS is to use two-way ANOVA, p-value < 0.05.

**Results**

The results of the pretest dan posttest flexibility between male and female athletes after being given static and dynamic stretching are presented in Table 2.

Based on Table 3, it can be observed that the flexibility of all four groups had an average pretest level and increased during the posttest.

*Normality Test*

The data normality test in this study used the Shapiro-Wilk method. The results of the data normality test carried out on each analysis group were carried out with the SPSS version 21.0 for windows software programme. The results of the normality test are presented in Table 4.

Based on the statistical analysis of the normality test using the Shapiro-Wilk test in Table 4, it shows that the pretest-posttest flexibility data for male and female athletes had p-values greater than or equal to 0.05, indicating that the data is normally distributed.

*Homogeneity Test*

A homogeneity test is useful to check the homogeneity of a sample. A homogeneous or heterogeneous sample drawn from a population. Univariate test with Levenes test. A test is declared unimodal if the univariate rule  $p > 0.05$ . Similar test results are shown in Table 5.

**Table 1.** 2 x 2 Factorial Research Design

Gender (B)	Stretching Exercise (A)	
	Static (A1)	Dynamic (A2)
Male (B1)	A1. B1	A2. B1
Female (B2)	A1. B2	A2. B2

Description: A1B1 - Athletes trained using static stretching exercises were male. A2B1 - Athletes trained using dynamic stretching exercises were female. A1B2 - Athletes trained using static stretching exercises were male. A2B2 - Athletes trained using dynamic stretching exercises were female.

**Table 2.** Pretest and posttest of flexibility atlet male.

No	Male					
	Stretching Static (A1B1)			Stretching Dynamic (A2B1)		
	Pretest	Posttest	Difference	Pretest	Posttest	Difference
1	12.2	13.3	1.1	12.0	13.2	1.2
2	11.3	12.2	0.9	11.6	14.0	2.4
3	11.2	12.4	1.2	11.1	13.5	2.4
4	10.8	11.3	0.5	10.9	11.6	0.7
5	10.6	11.5	0.9	10.3	11.7	1.4
Mean	11.22 cm	12.14 cm	0.92 cm	11.18 cm	12.8 cm	1.62 cm

**Table 3.** Pretest and posttest of flexibility atlet female.

No	Female					
	Stretching Static (A1B2)			Stretching Dynamic (A2B2)		
	Pretest	Posttest	Difference	Pretest	Posttest	Difference
1	12.1	14.6	2.5	11.8	12.3	0.5
2	11.7	14.3	2.6	11.7	12.4	0.7
3	11.3	14.5	3.2	11.2	12.6	1.4
4	11.0	14.1	3.1	11.1	12.7	1.6
5	10.7	13.9	3.2	10.7	12.3	1.6
Mean	11.36 cm	14.28 cm	2.92 cm	11.30 cm	12.46 cm	1.16 cm

**Table 4.** Normality test results.

Group		Shapiro-Wilk		
		Statistic	df	Sig.
Male	Pretest Static	0.918	5	0.515
	Posttest Static	0.945	5	0.698
	Pretest Dynamic	0.988	5	0.971
	Posttest Dynamic	0.869	5	0.263
Female	Pretest Static	0.981	5	0.941
	Posttest Static	0.962	5	0.823
	Pretest Dynamic	0.936	5	0.635
	Posttest Dynamic	0.867	5	0.254

**Table 5.** Homogeneity test results.

Group	Levene Statistic	df1	df2	Sig.
Pretest-Posttest Static	5.044	3	16	0.112
Pretest-Posttest Dynamic	4.275	3	16	0.601

**Table 6.** Hypothesis test results.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Stretching	1.404	1	1.404	5.433	0.033
Gender	2.965	1	2.965	11.468	0.004
Stretching * Gender	7.565	1	7.565	29.263	0.000

Based on the statistical analysis of homogeneity tests using Wilk's Levene Test in Table 5, the calculation results for pretest-posttest static p-values were greater than or equal to 0.05 (p-value 0.112 and p-value 0.601). This indicates that the data groups have a homogeneous variant, suggesting that the population has a similar variant or is homogenous.

#### *Hypothesis Test Results*

Research hypothesis testing is carried out based on the results of data analysis and interpretation of the analysis. two-way ANOVA using the SPSS software, specifically version 21. The results of hypothesis testing are shown in Table 6.

Based on Table 6, in the static and dynamic

stretching data, the F-value and p-value were found to be significant (F-value 5.433 and p-value 0.033 < 0.05). This confirms the hypothesis that there is a significant difference in the effect between static stretching and dynamic stretching on flexibility. The average static stretching group and dynamic stretching group had average differences of 0.53 cm. These results indicate that static stretching is more effective than dynamic stretching in improving flexibility.

Based on Table 6, the gender data (male and female) showed a significant difference (F-value 11.468 and p-value 0.004 < 0.05), confirming the hypothesis of a significant influence of gender on flexibility. The average flexibility for males was 1.27

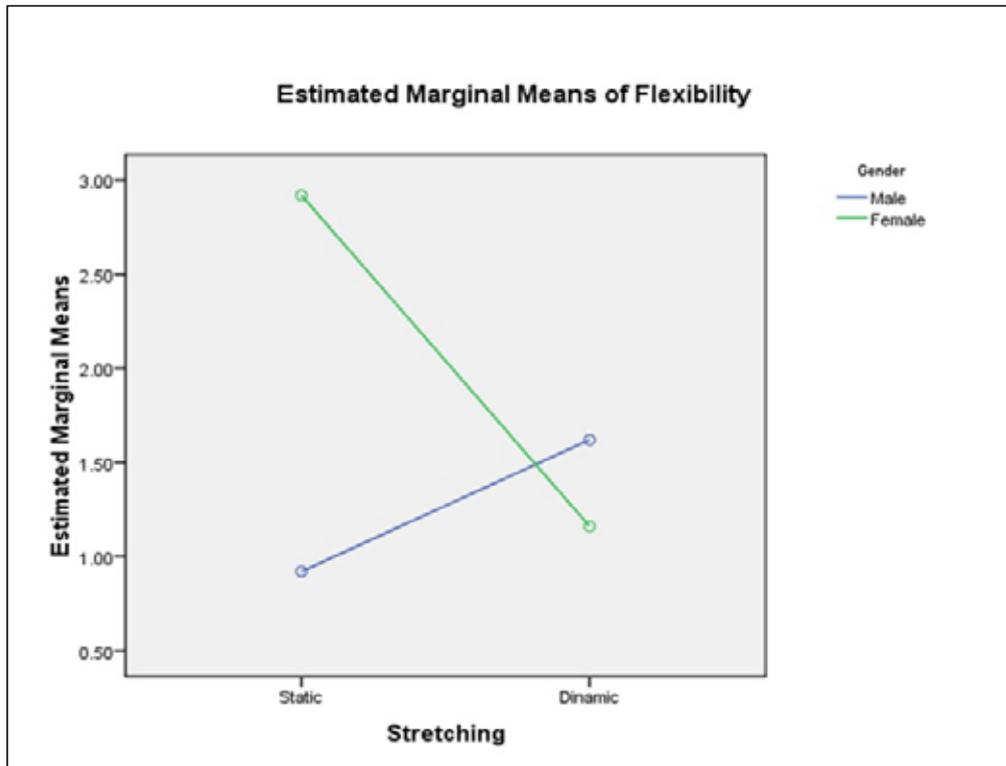


Figure 1. Interaction between stretching (static and dynamic) and gender (male and female) on flexibility.

Table 7. Tukey Test Result.

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A1B1	A2B1	-0.7000	0.32156	0.172	-1.6200	0.2200
	A1B2	-2.0000*	0.32156	0.000	-2.9200	-1.0800
	A2B2	-0.2400	0.32156	0.877	-1.1600	0.6800
A2B1	A1B1	0.7000	0.32156	0.172	-0.2200	1.6200
	A1B2	-1.3000*	0.32156	0.005	-2.2200	-.3800
	A2B2	0.4600	0.32156	0.500	-0.4600	1.3800
A1B2	A1B1	2.0000*	0.32156	0.000	1.0800	2.9200
	A2B1	1.3000*	0.32156	0.005	0.3800	2.2200
	A2B2	1.7600*	0.32156	0.000	0.8400	2.6800
A2B2	A1B1	0.2400	0.32156	0.877	-0.6800	1.1600
	A2B1	-0.4600	0.32156	0.500	-1.3800	0.4600
	A1B2	-1.7600*	0.32156	0.000	-2.6800	-0.8400

Note: the results of the Tukey test calculation on the asterisk sign (\*) show that the interaction pairs or pairs that are significantly different (significant) are: A1B1-A1B2, A2B1-A1B2, A1B2-A2B2, while the other pairs declared to have no difference in effect are: A1B1-A2B1, A1B1-A2B2, and A2B1-A2B2.

cm, while for females, it was 2.04 cm, with an average difference of 0.77 cm. These findings indicate that females have better flexibility than males. Additionally, based on Table 6, the interaction data between stretching (static and dynamic) and gender (male and female) also showed a significant result (F-value 29.263 and p-value 0.000 < 0.05). This supports the research hypothesis of a significant interaction between stretching methods and gender

on flexibility. The graphical representation of the interaction test results between stretching (static and dynamic) and gender (male and female) on flexibility is presented in Figure 1.

After it is tested that there is an interaction between stretching (static and dynamic) and gender (male and female) on flexibility, it is necessary to conduct further tests using the Tukey test. Further test results can be seen in Table 7 below:

**Table 8.** Tukey HSD Test Result.

Group	N	Subset	
		1	2
A1B1	5	0.92	
A2B2	5	1.16	
A2B1	5	1.62	
A1B2	5		2.92
Sig.		.172	1.00

The results of the Tukey HSD analysis to determine which training group improved flexibility better are in Table 8 as follows.

Based on the Tukey HSD test results in Table 8, the A1B2 group (female athletes trained using static stretching) is in a different subset column. Based on this it can be concluded that the A1B2 group is better than the A1B1, A2B2, and A2B2 groups.

## Discussion

The results of the first analysis showed that static stretching was better than the dynamic stretching group on flexibility. This is in accordance with the results of research on the comparison of the effectiveness of static stretching with dynamic stretching on increasing hamstring muscle flexibility with a total of 74 subjects who meet the criteria. The results showed that static stretching was more influential than dynamic stretching in increasing the flexibility of the hamstring muscles [24]. Static and dynamic stretching can basically both help improve flexibility. However, static stretching is considered more suitable for increasing flexibility, while dynamic stretching is more suitable for increasing muscle power than for increasing flexibility and joint range of motion. A total of 20 female students in their final year from various departments at Universitas Pendidikan Sultan Idris (UPSI) were involved in this study. Subjects were selected based on body mass index and never actively exercising. The wills were divided into two groups. Group A (n=10) will perform five types of static stretching exercises while the second group B (n=10) will perform five types of dynamic stretching exercises. They will do a 5-minute warm-up exercise of jogging before starting the stretching. The stretching exercises will be performed in three alternate days for four weeks. The results indicated that static stretching exercise is more effective in increasing the flexibility of the hamstring compared to dynamic stretching exercise and also has results on it in reducing the risk of injury [25].

Static stretching is performed by pulling the muscle to its maximum range and maintaining this position for a specified duration. One of the advantages of static stretching is that it facilitates the GTO. Static stretching performed on the tendon muscle unit has been known to activate

the GTO. Static stretching has been shown to be very effective in increasing hamstring length [26]. Static stretching is a stretching exercise that is done by maintaining a stretched position for a long time, the movements are slow and smooth. When the muscle is stretched, the muscle spindle is also stretched. Muscle spindles will report changes in length and how fast the change in length occurs and provide signals to the spinal cord to forward information to the central nervous system. The muscle spindle will trigger the stretch reflex, also known as the myostatic reflex, to try to resist the changes in muscle length that occur by contracting the stretched muscle [27]. One of the reasons for maintaining a stretch for a long period of time is that when the muscle is maintained in the stretched position, the muscle spindle will get used to the new muscle length and will reduce the signal. Gradually the stretch receptors will be trained to provide greater length to the muscle. When the muscle is stretched slowly and gently, the Golgi tendon organ will be optimally stimulated, so that stretching will occur in muscle fibres and fascia where the number of sarcomeres increases and fascia is stretched. Stretch reflex has two components, namely the static component and the dynamic component. The static component is found throughout when the muscle is stretched. The dynamic component is found only at the end when the muscle is stretched and the response causes an immediate change in muscle length. The underlying reason that the stretch reflex has two components is because there are two intrafusal muscle fibres: nuclear chain fibres responsible for the static component and nuclear bag fibres responsible for the dynamic component. The muscle response to stretching basically occurs in the elastic components (actin and myosin) and the tension in the muscle increases sharply, the sarcomere lengthens and if this is done continuously the muscle will adapt.

Static stretching has a relaxing effect, lengthening effect on muscles, increasing ROM, reducing muscle stiffness and also reducing the risk of acute muscle injury [14]. In this method, there is no stretch reflect as in the dynamic stretching method. The movement of the joint to expand its space can be done maximally and continuously according to its ability, then maintained for some time and repeated several times according to the instructions of the trainer. When the muscle is passively stretched the initial elongation occurs in the sarcomere component and the tension increases drastically. When the strain is removed, the sarcomere will return to its initial length before being stretched. This tendency of the muscle to return is called elasticity. Meanwhile, when the muscle is actively stretched, the first effect will occur on elastin (actin and myosin), muscle tension increases sharply, sarcomeres lengthen and if done

continuously the muscle will adapt and will last for some time Flexibility itself has a relationship with the breadth of joint motion or range of motion. When flexibility increases, joint range of motion will increase.

The results of the second analysis found that female athletes have better flexibility than male athletes. Gender is one of the factors that affect flexibility and a person's ability to move joints. Most women will be more flexible than men [28], because it is due to differences in bone and joint structure. Females will have a lower torso body than males after adolescence. This is because females have a lower centre of gravity and shorter legs than males. Sex difference is one of the factors that affect flexibility. Girls will tend to be more flexible than boys in childhood when entering adulthood there will be little difference. Women are more flexible than men due to anatomical and hormonal influences. Women have wider hips than men or maybe because women do activities or sports related to good physical fitness, such as dancing, gymnastics, or swimming.

Another difference is due to the different anatomical structure of soft tissues between the two, namely muscles, tendons, ligaments and fascia in men are larger and thicker, which reduces the flexibility of these tissues, and the hormone estrogen in women also has an effect on increasing the elasticity of these soft tissues. Grimston tried to analyse ankle flexibility based on age and gender, and more specifically, the study concluded that age and gender are some of the factors that affect a person's flexibility. Where women have better ankle flexibility than men, and the growth factor of age makes a person's flexibility ability decrease (both male and female) [29]. Further findings showed for the flexibility test, women achieved a greater distance than men for the sit and reach test (p-value <0.001) [30].

Other literature also reveals several causes that can be used as a reference or basis related to women having better flexibility than men. The literature review that women's flexibility is better than men's is due to several things, such as: the factor of decreasing blood volume when the muscle is extending is better in women than in men, in other words it can be said that the mechanism of blood flow in the arteries in women is better than men [31], the influence of the hormone estrogen which makes differences in muscle composition in men and women, where the composition of female muscles is less than the composition of muscles in men, causing flexibility in women better than men [32], and another factor is the fasciculation of tendon muscles that is better in women than in men, thus making women more ideal in performing extension movements [33].

Based on the results that have been stated that there is a significant interaction between stretching (static and dynamic) and gender (male and female) on flexibility. The results showed that the static stretching group was a more effective method used for female athletes and the dynamic stretching group was more effective for male athletes. Some of the theories above are actually enough to explain that women's flexibility will indeed be superior to men, but what needs to be realised in this case is that the training factor in sports can be one of the things that affects flexibility itself. Back to the nature of sport, which is a systematic movement or sports activity for a long time, improved progressively and individually which leads to the characteristics of human psychological and physiological functions to achieve specified goals [34], It is not impossible for a male athlete to achieve the same flexibility as a female, if the male athlete is trained harder than the female athlete. Although we should be aware that men will have a heavier training dose in creating flexibility if they want to match women, given the physiological factors that favour women over men.

## Conclusions

Based on the results of the research and data analysis, the following conclusions are drawn:

- There is a significant difference in influence between static stretching and dynamic stretching on flexibility (p-value  $0.033 < 0.05$ ). Static stretching is more effective than dynamic stretching in improving flexibility.
- There is a significant difference in effect between male and female gender on flexibility (p-value  $0.004 < 0.05$ ). Females exhibit better flexibility compared to males.
- There is a significant interaction between stretching (static and dynamic) and gender (male and female) on flexibility (p-value  $0.000 < 0.05$ ). The static stretching group is more effective for female athletes, while the dynamic stretching group is more effective for male athletes. Incorporating both static and dynamic stretching methods in training can effectively enhance flexibility.

Badminton coaches and practitioners are encouraged to consider gender-specific characteristics and muscle capabilities when designing training programs, especially focusing on flexibility, to improve athlete performance and reduce the risk of injury in badminton athletes.

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## Conflict of interest

We are not aware of any conflict of interest related to this publication. Also no financial aspects were included in this study which might have affected

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# Physical activity and academic performance in students from same primary education school

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

## Abstract

**Background and Study Aim** Recent researches has demonstrated the relationship between physical activity levels and academic performance in schoolchildren. Most of them have sampled students from different schools and cities. Sometimes academic performance was influenced by other factors such as the type of teaching, the teaching staff or, for example, the assessment system. This research has tried to associate the practice of out-of-school physical activity with academic performance in a group of students, with the peculiarity that they all belonged to same Elementary school.

**Material and Methods** 120 students (67 boys and 53 girls), aged between 8 and 12 years, participated in this study once their parents or guardians were informed about the characteristics of the study. Academic performance was calculated from the average grades provided by their teachers in the first term. Physical activity levels were calculated using the APALQ questionnaire, categorising students into two types: active or sedentary. In the presence of a normal distribution, the difference between groups was obtained using Chi-Square and Student's t-test. In those cases where the distribution was not normal, comparison was carried out using the Mann Withney U.

**Results** The analysis of results showed that active students obtained significantly higher grades than sedentary students ( $8.15 \pm 1.17$  vs.  $7.35 \pm 1.15$ ;  $p=0.042$ ). This circumstance is maintained when analysing the results according to the students' gender, although it is only significant in the case of girls ( $8.08 \pm 1.22$  vs  $7.03 \pm 0.87$ ;  $p=0.036$ ).

**Conclusions** The practice of physical activity during non-school hours had a positive influence on the academic performance of the students analysed, even though they were from the same school.

**Keywords:** academic performance, physical activity levels, children, physical education, extra-curricular sports, healthy habits.

## Introduction

This research aims to demonstrate the relationship between the practice or extra-curricular physical activity and academic performance in children belonging to the same primary school. To this end, the academic averages obtained by a group of students from third to sixth grade will be analysed. Results are shown according to children physical condition: sedentary versus active.

It is considered that childhood is a key stage in which children form healthy habits or acquire new knowledge, as their personality is in the process of formation [1, 2]. Along this lines, Gámez-Calvo et al. [3] stated that during this period students' concept of personal identity is strengthened, thus creating conditions for them to learn useful habits that they can incorporate into their lifestyles for adulthood.

In the same work, Gámez-Calvo et al. argued that the academic performance of our schoolchildren could be influenced by different variables, all of which are connected to students' lifestyles [3]. For example, Lee et al. [4] found a direct relationship between sleeping hours and academic performance, while Kristjánsson et al. [5] linked it to students'

eating habits or even body mass index. However, in recent years, there has been a trend to analyse whether physical exercise might be related to better school success, leading to numerous systematic reviews linking these variables [6, 7, 8, 9].

It is clear that regular physical activity is essential for our schoolchildren to achieve optimal growth and development [10, 11, 12]. Also, just as a decrease in levels of physical activity could have an impact on the physical and mental health of our students [13]. In terms of official recommendations for physical activity, national and international bodies agree that school children (6-12 years) should get at least 60 minutes of moderate to vigorous physical activity per day to improve their health and well-being [1, 10].

Therefore, we should ask ourselves whether this improvement in health promoted by physical exercise will be reflected in cognitive improvements in general and, particularly, in the academic performance of our students. Regarding cognitive improvements, Dywer [14] concluded that schoolchildren who exercised were more responsible and respectful of the rules. Rosa-Guillamón et al. [15] also observed improvements with respect to group work with peers, as well as greater organisational skills. Finally, several researchers found that brains

of children who engaged in systematic exercise were more stimulated, increased motivation towards academic contents and improved teaching and learning processes [16, 17, 18].

That regular practice of physical activity promotes better academic performance is a conclusion reached by numerous reviews of the literature on the subject [8, 9, 19, 20, 21]. Specifically, when analysing studies with Primary School students similar to ours, we highlight the most recent ones published in our country. Isorna et al. [22] found a significant relationship between practicing physical exercise and obtaining better grades in students aged 6 and 12 years. In another publication, with 223 students from 3rd to 6th grade of primary school, Prieto & Martínez [23] concluded that students who were more physically active had an increase in academic performance and had better grades in the area of mathematics. Pros et al. [24] indicated that the practice of extracurricular physical activity significantly affected academic performance in language, mathematics and languages, after analysing 518 primary school students.

With regard to research made out of Spain, Fritz et al. [25] established a positive relationship between physical exercise and academic performance in 338 children aged between 6 and 8 years. Faught et al. [26], after studying 4.253 pupils aged 10 and 11, concluded that an active lifestyle was associated with better grades, especially in mathematics. In the same way, Booth et al. [27] reported that physical activity predicted academic performance in English, mathematics and science in a study of 4.755 students aged 9, 10 and 11. Wang et al. [28] found a positive correlation between physical fitness and academic achievement after analysing 1.065 children from Taiwan.

In contrast, and in areas of study close to our research, there are also studies in which the authors found no causality between the practice of physical exercise and better grades in primary school students [29, 30, 31, 32]. In the light of the above, we consider it necessary to analyse whether the practice of extracurricular physical activity will have an effect on the academic performance of students.

*Purpose of the Study.* The study purpose was to identify the relationship between the practice of extra-curricular physical activity and academic performance in a group of students, all belonging to the same educational centre, a primary school in the city of Murcia, Spain.

## Materials and Methods

### *Participants*

This research was based on a descriptive, non-experimental, quantitative study. The sample belonged to a Primary School in the city of Murcia, Region of Murcia, Spain. A total of 120 children,

67 boys and 53 girls, aged between 8 and 12 years, participated in the study during the 2021/2022 school year. Before starting the data collection, the head teacher of the school was informed of the type of study to be carried out. The participating students were then asked to provide signed consent by their parents or guardians, who were previously informed of the characteristics of the study. This study has been approved by the University of Murcia's Research Ethics Commission (November 2021).

### *Research Design*

The Assessment of Physical Activity Levels Questionnaire (APALQ), translated into Spanish and validated by Jurado-Castro et al. [33], was used to categorise whether or not students were physically active outside school. Students were considered "active" if they scored 11 or more points on the questionnaire. Regarding academic performance, the tutors of each year were asked for the report cards of the first term of the academic year, detailed by subject. As the students belonged to the same school, the results obtained allow us to link the study variables (physical activity and academic performance), eliminating the possible contaminating variables that could arise when using academic performance from different schools (different teachers, methodologies, textbooks or assessment systems, etc.).

### *Statistical Analysis*

The data collected were analysed using IBM SPSS Statistics for Windows, Version 28.0 (Armonk, NY: IBM Corp). First, the normality of the data was analysed according to the different variables, using the Kolmogorov-Smirnov statistic. In the presence of a normal distribution, the difference between groups was obtained using Chi-Square and Student's t-test. In those cases where the distribution was not normal, the comparison between means was carried out using the Mann Withney U statistic.

## Results

The purpose of this research was to analyse physical activity levels in primary school students and its relationship with their academic performance.

Firstly, with regard to the descriptive analysis (Table 1) of the physical activity variable, it was observed that, analysing the total number of pupils without distinction of gender, 80.8% of those surveyed were active, compared with 19.2% who were sedentary.

According to gender, this difference was not significant (Student T;  $p=0.061$ ). 86.5% of boys did engage in physical activity, while this value fell to 72.6% of girls. Same circumstance was repeated in all grades where, although there was no significant difference by grade ( $p=0.603$ ), the percentage of active pupils was higher than that of sedentary

pupils for every year (third, fourth, fifth or sixth).

**Table 1.** Out-of-school physical activity practice according to students' gender and scholar grade

Category	Sedentary	Active	Sig. (p)
All (n=120)	23 (19.2%)	97 (80.8%)	-
<b>Gender</b>			
Boys (n=67)	9 (13.5%)	58 (86.5%)	0.061
Girls (n=53)	15 (28.4%)	35 (72.6%)	
<b>Year</b>			
Third (n=33)	8 (24.2%)	25 (75.8%)	0.603
Fourth (n=26)	5 (19.5%)	19 (80.5%)	
Fifth (n=26)	3 (11.5%)	23 (89.5%)	
Sixth (n=35)	9 (25.7%)	26 (74.3%)	

On analysing the results according to year, we could see how, in all years, the percentage of children who practised PA outside school hours was higher in boys than in girls. In 5th grade of primary school, 100% of the male pupils participating in this study were considered "active". In any case, the chi-square statistic by year group also gave a value greater than 0.05, so that these differences were not significant according to gender and year group.

We then proceeded to study the relationship between physical exercise and academic performance of the participants. It was calculated that the academic average for physically active students was higher than for sedentary students (8.15±1.17 vs. 7.35±1.15). Furthermore, these differences were significant (p=0.042), which indicates that students who practised physical activity outside school hours had higher academic performance than sedentary ones (Table 2).

**Table 2.** Academic performance categorised by gender and students' year

Category	Average Grade – Sedentary Students		Average Grade – Active Students		Sig. (p)
	Mean	SD	Mean	SD	
All (n=120)	7.35	1.15	8.15	1.17	0.042*
<b>Gender</b>					
Boys (n=67)	7.74	1.29	8.14	1.13	0.408
Girls (n=53)	7.03	0.87	8.08	1.22	0.036*
<b>Year</b>					
Third (n=33)	7.50	1.15	8.82	0.68	0.002*
Fourth (n=26)	7.47	1.29	7.84	1.52	0.612
Fifth (n=26)	9.35	0.16	7.82	1.24	0.026*
Sixth (n=35)	7.57	0.75	8.13	0.99	0.099

\*Significant Difference p<0.05

When performing the same test, but differentiating the results according to the gender of the students (Table 2), it was observed that academic performance was better in both boys and girls for those students who practised physical activity outside school. Thus, the mean academic performance of boys who exercised was higher than that of sedentary students (8.14±1.13 vs. 7.74±1.29), although this difference was not considered significant (p=0.408). In the case of girls, the difference in academic performance between active and sedentary girls also occurred (8.08±1.22 vs. 7.03±0.87). Moreover, in this case, this difference was found to be significant (p=0.036).

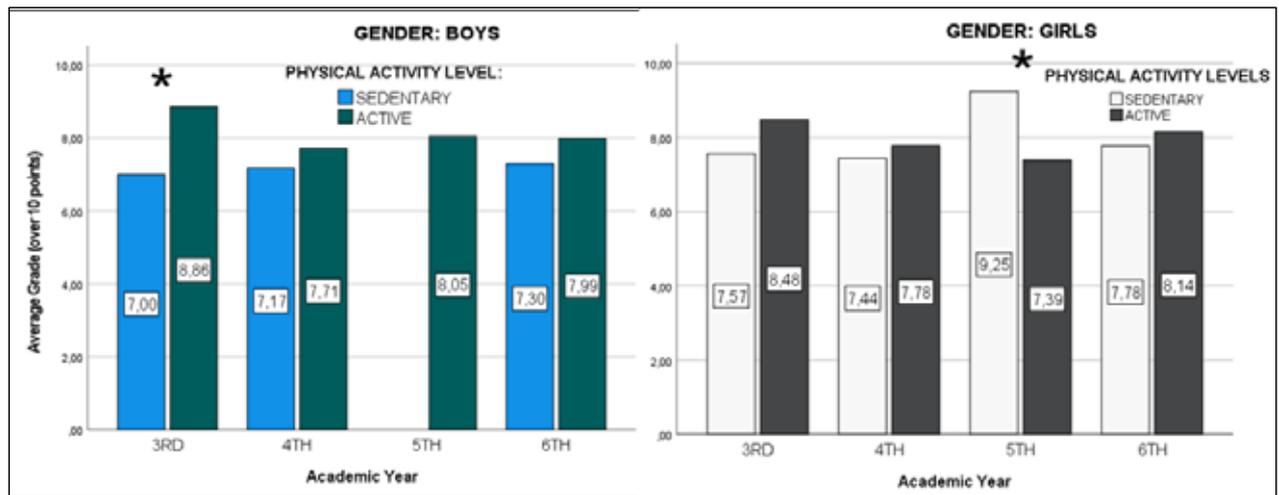
And as a function of year? In this case we again applied the Mann Withney U statistic because of the non-normal distribution of the results. Thus, as shown in Table 2, in 3rd grade the academic performance of those students who practised extracurricular physical activity was significantly higher in active students than in sedentary students (8.82±0.68 vs. 7.50±1.15), with a p-value of 0.002. In the 5th and 6th grades of primary school, the academic performance was higher in pupils who exercise, although these differences were not considered significant. It is noteworthy that, in the case of 5th grade of Primary, the difference is reversed. Students categorised as sedentary obtained a higher academic performance average than active students (9.35±0.16 vs. 7.82±1.24), being, moreover, significant (p=0.026).

Finally, for boys, the active students obtained better marks than the sedentary students (Fig. 1). Specifically, in the case of 3rd grade, this difference (8.86 vs 7.00) was significant, with a p-value of 0.041 after applying the Mann Withney U statistic. Analysing the girls by year, we can see that in the third, fourth and sixth years of primary school, the active girls obtained higher average marks, although this difference was not significant in any case. The fifth year of primary school stands out, where sedentary pupils obtained higher average marks (9.35) than active pupils (7.49), and this difference was significant (p=0.035).

## Discussion

The purpose of this manuscript was to analyse the relationship between the practice of physical activity and academic performance in pupils belonging to the same primary school. Firstly, with regard to descriptive analysis, it was observed that most of the students from analysed school, 80.8%, engage in PA out of scholar hours compared to 19.2% of sedentary pupils. This data reveals that the percentage of physically active children is large, in line with recent research on the school population in our Spain [34, 35, 36].

In contrast, the values obtained in our school differ from those found by Alfonso-Rosa et al.[37],



\*Significant difference  $p \leq 0.05$

**Figure 2.** Academic performance as a function of physical activity level. Categorised by grade and gender of students

for whom, in the context of the same population group, most of the students studied were sedentary. As mentioned in the methodology section, the sample of this study belonged to the same school. Specifically, to a subsidised school in the centre of the capital of the Region of Murcia, Spain, where most families belonged to a medium-high socio-economic stratum. The economic level is linked to the levels of physical activity of schoolchildren [1, 38, 39]. In our case, the results obtained coincide with those published by Cano-Garciñuno et al. [40] and Ramos et al. [41] who, after analysing levels of sports practice according to the economic status of families, concluded that those students belonging to environments with greater purchasing power were significantly more physically active than the rest.

With regard to associating the level of physical activity with academic performance, we would like to mention, again, that, as the students belong to the same centre, results are not influenced by the type of institution, type of teaching staff, methodologies or type of assessment, among others [31, 42]. Therefore, we start from a homogeneous level of demand and assessment criteria, similar for all students and only differentiated by their grade. With this premise, the analysis of the results has allowed us to conclude that those students who practice exercise after school hours obtained higher academic performance compared to more sedentary students (mean score of  $8.15 \pm 1.17$  vs.  $7.35 \pm 1.15$ ) and, moreover, this difference was significant ( $p = 0.042$ ).

This circumstance coincides with most of the reviews published to date in Spain [43, 20]. Also in the international context [8, 9, 28], where it was concluded that higher levels of sports practice were positively associated with better academic performance.

Regarding foreign studies carried in Spain, with

the condition of analysing students belonging to the same school, our conclusions coincide with Prieto & Martínez [23], who analysed 232 students from the same school where the best average grades (especially in mathematics) were obtained for students who accumulated higher levels of physical activity. The same conclusion was obtained by Alfonso-Rosa et al. [37] after studying the grades of 50 pupils aged 9-10 years in a school in Seville.

One explanation for these results can be found in the studies by Hillman et al. [44] and Ibáñez [45], who concluded that the fact of practising more hours of exercise did not affect a reduction in study hours in children and adolescents. As indicated by WHO [1] and Luque et al. [20], systematised physical activity contributes to the development and maintenance of the cognitive functions of students. It will be reflected in their better academic performance, compared to those students who only participate in academic activities [46].

In terms of gender, active boys obtained better results than sedentary ( $8.19 \pm 1.13$  vs.  $7.79 \pm 1.31$ ). This was repeated in girls ( $8.02 \pm 1.22$  vs.  $7.03 \pm 0.87$ ) where, moreover, the differences were statistically significant ( $p = 0.036$ ). Several publications show similar results. Hernández & Pórtolés [47] and Álvarez-Bueno et al. [48], established a direct relationship between the practice of physical exercise and academic performance, with significant results in the case of girls. In a previous study, Calvo-Pacheco et al. [49] with schoolchildren in Tenerife (Spain) observed that, within the group of physically active students, girls obtained significantly better grades than boys. In contrast, our results differ from those published by Ávila-García et al. [50], who, after analysing the results of 152 students in the second year of primary school, found that, in the case of girls, academic performance was inversely

proportional to exercise.

Finally, the results were analysed according to the academic year of the students. Thus, we were able to observe how in 3rd year, academic performance in those students who practise PA is significantly higher in active students than in sedentary students ( $8.66 \pm 0.87$  vs.  $7.26 \pm 1.21$ ), with a p-value of 0.024. This was similar in 5th and 6th year, although the differences were not significant. In this sense, there are few studies that have analysed this variable according to the students' year of study. Even so, in the research by Sibley & Etnier [51], it is observed that the differences in grades between active and sedentary students become greater as they advance in age and the grades become more demanding. This fact is even more important in our case, since we are dealing with the same school where the differences in terms of demands, teachers and methodology are more evident from year to year.

## Conclusions

The school students analysed in this study with higher levels of physical activity out of school hours obtained significantly better academic performance than those who were more sedentary. This situation was maintained when analysing the results according to gender, and was statistically significant in the case of girls. The analysis by grades showed a positive relationship between exercise and better grades in three of the four grades analysed (third, fifth and sixth year of Primary Education).

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## Description of kinesthetic and kinetic motor praxis in older preschool children with logopathology

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

### Abstract

**Background and Study Aim** The development of kinesthetic and kinetic hand praxis in older preschool children is a prerequisite for successful learning in school conditions. The purpose of this study is to identify the current state of neuromotor functionality kinesthetic and kinetic hand praxis, which affects readiness for schooling, in older preschool children with speech pathology.

**Material and Methods** Research methods are aimed at studying the components of neuromotor functionality: kinaesthetic and kinetic wrist praxis. To study the kinesthetic praxis of the hands, the task "Fine motility of the fingers" was used. Kinetic praxis was studied during the task "Differentiated movements of the hand". They studied the formation of object-kinetic praxis during "Performing actions with objects".

**Results** The results of the experimental study give a clear idea that there are significant differences in the formation of neuromotor functionality between the groups of children with logopathology and those with normotypical psychophysical development. In older preschool children with speech disorders, low abilities were found when performing tasks of kinaesthetic and kinetic praxis: wrist (fussy movements of fingers and hands; searching for the right position, the incorrect joining of fingers, hand positions; the presence of perseveration of previous movements; underdeveloped fine motility of fingers of hands; difficulties in subject activities). Children are passive during classes, they need constant support from the teacher.

**Conclusions** The revealed unformed state of neuromotor functionality confirms our hypothesis. Impairment of neuromotor function of kinesthetic and kinetic hand praxis is present in a significant percentage of preschoolers with speech disorders, which becomes a characteristic feature of this category of children and affects further physical, intellectual, and semiotic development.

**Keywords:** children of older preschool age, wrist praxis, speech disorder, kinesthetic hand praxis, kinetic hand praxis.

### Introduction

Neuromotor functionality of the cognitive component of speech readiness includes wrist, oral, articulatory kinaesthetic and kinetic praxis. Neurophysiological research shows that praxis (Greek: praxis – action) is a system of voluntary, purposeful motor actions that provide practical skills for various types of activities. Motor control and movement control are organized by the frontal lobe of the premotor cortex of the cerebrum. Its activity involves the sequential synthesis of separate motor impulses into single "kinetic structures" that are automated during training and provide a dynamic process of complex movements and motor skills. Luria [1] divided all praxis actions into two types of praxis: kinaesthetic praxis (afferent) is sensory and provides insight into one's own body. The information collected from the sense organs (from sensory neurons) is transformed into nerve impulses and reaches the central parts of the brain via afferent pathways, in particular, the parietal

lobe of the left hemisphere; kinetic praxis (efferent) carries out motor activity. From the premotor zone of the cortex of the frontal lobe, electrical impulses are spread, which activate the muscle, tendon and joint systems.

Subject, finger, oral and articulatory types of praxis are distinguished [2]. The ontogenesis of the child is connected with the gradual development of *subject praxis* [3]. Manipulation actions with the subject, in addition to the formation of cognitive processes (attention, memory, thinking, imagination, perception, etc.) are also aimed at the development of visual and auditory gnosis, wrist praxis. Mastery of subject activity determines the readiness of an older preschooler in school conditions to master more complex educational actions – abstract, symbolic (symbolic subject praxis is an action with an object; non-symbolic – a conditional action without an object) [4].

Research by scientists testify that finger motility, namely, *wrist praxis* develops in parallel with speech mechanisms and cognitive processes [5]. The development of fine motor skills is a

prerequisite for children to master oral [6, 7] and written communication [8, 9] and is evaluated as an indicator of general mental development [1]. The motor activity of the fingers through kinesthetic impulses innervates speech zones in the cerebral cortex, in particular Broca's center. Insufficient development of fine motor skills in older preschool children may indicate a delay in speech functions.

Research in neuropsychology makes it clear that various forms of apraxia arise as a result of damage to the left hemisphere [1, 2]. In particular, damage to the parietal region leads to violations of the kinesthetic organization of movements (fingers, oral, articulation system); a frontotemporal lesion causes disorders of dynamic (kinetic) praxis (slowness of action, difficulties when switching from one movement to another, presence of perseveration, etc.); parietal-occipital damage leads to peculiar violations of spatial praxis [4].

*Research Hypothesis.* Taking into account scientific research [10, 11], we can assume that the lack of neuromotor functionality is present in a significant percentage of preschoolers with speech disorders. And this becomes a characteristic feature of this category of children [12].

Experimental research includes variational-statistical (quantitative) and qualitative analysis of study materials [13], which allows understanding of the structure of the studied phenomenon, its variability, dependence, relationships and principles of functioning [14].

*Purpose of the Study.* The purpose of this study is to identify the current state of neuromotor functionality kinesthetic and kinetic hand praxis, which affects readiness for schooling, in older preschool children with speech pathology.

## Materials and Methods

### *Participants*

The study included 607 older preschool children (5–6 years old), of which 250 had normotypical psychophysical development and 357 had logopathology (dyslalia (n = 212), stuttering (n = 40), rhinolalia (n = 28), dysarthria (n = 77)).

### *Ethical consideration*

Ethical approvals. During the collection of experimental data, the consent of the parents of the study participants was obtained. Appropriate ethical norms and rules are followed; no moral pressure was exerted on the research representatives. All the mentioned procedures with the participation of the respondents corresponded to the ethical standards of the institutional and national research committees, as well as the principles of the Declaration of Helsinki.

### *Research Design*

The confirmatory experiment was conducted

by speech therapists and educators on the basis of preschool educational institutions. Research of neuromotor function was carried out individually with each child separately. The duration of tasks is about 20 minutes. The assessment of the results of the tasks was immediately recorded in the research protocol. The duration of the ascertainment experiment was 3 months.

The research of neuromotor functionality in children with logopathology takes place through the study of wrist praxis. The kinesthetic praxis – will determine the child's ability to perform certain differentiated movements (fingers) and exercise control over them. The kinetic praxis – indicates the preschooler's ability to combine various movements into a coordinated action (performing a certain activity with the fingers).

### *Instruments*

The state of formation of neuromotor functionality is studied using methods aimed at researching kinesthetic and kinetic praxis of the wrist [1, 4]. The content of the neuromotor component, methods, evaluation criteria and scoring system are outlined in Table 1.

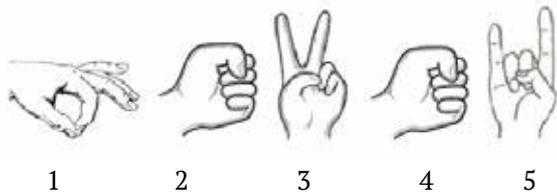
**Table 1.** Research methods of neuromotor functionality.

The content of the neuromotor component	Methods	Evaluation criteria	General number points
Wrist praxis	Amiel-Tison, et al. [5], Luria [1]	kinesthetic praxis: - fine motor skills of the fingers	2
		kinetic praxis: - differentiated hand movements	2
		- performance of actions with objects	2
Total points			6

### *Procedure*

To study wrist kinesthetic praxis, the task 'Fine Motility of Fingers' was employed. During this task, children were presented with various finger positions and instructed to replicate them, first with the right hand and then with the left. The positions were as follows, corresponding to the labels in the figure: 1 - forming a ring by connecting the thumb and forefinger; 2 - making a fist by clenching all fingers; 3 - extending the index and middle fingers forward; 4 - again making a fist; 5 - extending the index and little fingers forward. The task duration was limited to 2 minutes. The depicted hand

positions were designed based on established finger praxis developmental templates [15] (see Fig. 1).



**Figure 1.** Demonstration of the 'Fine Motility of Fingers' task [15].

Kinetic praxis is investigated through the task 'Differentiated Movements of the Hand'. In this task, children are presented with various hand positions and instructed to replicate them. The positions are as follows, with corresponding labels in the figure:

**I. Simultaneous Performance with Both Hands:**

1 - Right hand clenched into a fist, left hand turned downwards with an open palm.

2 - Left hand clenched into a fist, right hand pointing down with an open palm.

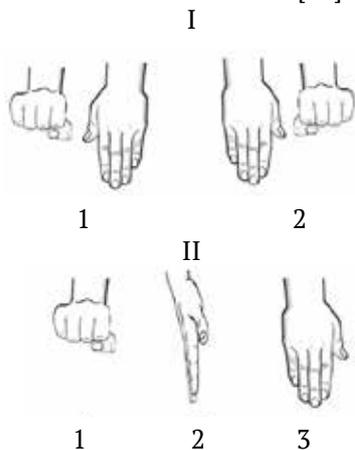
**II. Sequential Execution with One Hand (first with the right hand and then with the left hand):**

1 - Hand clenched into a fist.

2 - Hand opened with the 'rib' downward.

3 - Hand with an open palm down hitting the table.

The task's duration is limited to 2 minutes (see Fig. 2). The depicted hand positions were designed based on established templates for the development of differentiated hand movements [15].



**Figure 2.** Demonstration of the 'Differentiated Movements of the Hand' task [15]."

**Study of Subject Praxis:**

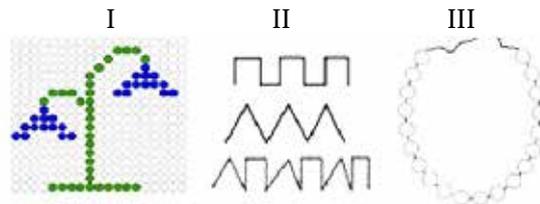
The third task involves 'Performing Actions with Items.' In this task, the child is instructed to carry out a series of actions involving objects:

**I. Mosaic Pattern Arrangement:** The child lays out a mosaic pattern based on the provided sample.

**II. Graphic Drawings:** The child creates graphic drawings.

**III. Stringing a Necklace:** The child threads beads onto a string to create a necklace.

Each group of tasks is allotted a duration of 5 minutes (see Fig. 3). The actions were designed to assess different aspects of subject praxis and are depicted in Figure 3.



**Figure 3.** Demonstration of the 'Performing Actions with Items' task."

Results of the three tasks are evaluated as follows:

- 2 points indicate that the child completes all tasks correctly;
- 1 point is given when the child requires stimulating assistance or makes one or two mistakes;
- 0 points are assigned if there are more than two mistakes.

The highest achievable score for each task is 2 points. Task results are assessed using a three-point scale (2; 1; 0). The total maximum score across the three tasks is 6 points.

*Statistical Analysis*

The disparities in research findings between children with logopathology and those with normotypical psychophysical development have been verified through the application of Student's parametric t-test. The independent sample t-test has been employed to assess the data. During the course of the statistical analysis, we examine two hypotheses:

**H0 (Null Hypothesis):** The differences observed between the groups of children with logopathology and those with normotypical development are incidental or random.

**H1 (Alternative Hypothesis):** The differences between the groups are statistically significant or reliably significant.

In the assessment process, if the calculated tem statistical value is less than the critical ttab value, we accept hypothesis H0; conversely, if the calculated tem statistical value is greater than or equal to the tabular ttab value, we accept hypothesis H1. The confidence level (or significance level) chosen for this analysis is set at  $p = 0.05$ , which signifies a 95% level of confidence in the reliability of the experimental results."

**Results**

The analysis of hand kinesthetic praxis for the task 'Fine motility of fingers' using the Student's t-test revealed significant findings. The empirical indicators demonstrated that the measured values

exceeded the tabular values by a considerable margin. This indicates a notable disparity in motor organization between older preschool children with normotypical psychophysical development and their peers with logopathology. The p-value suggests statistical significance in favor of normotypical development. Furthermore, in the context of normotypical development, the average indicators of the scoring system displayed a remarkable difference compared to children with speech disorders. Specifically, normotypical children exhibited notably higher scores, while the results for preschoolers with dyslalia and stuttering were lower. The observed trends indicated the greatest deviation from the norm in children with rhinolalia and dysarthria, emphasizing the impact of speech development on the motor organization of fingers (Table 2).

Examination of kinetic praxis research materials for the task ‘Differentiated movements of the hand’ revealed noteworthy results. The empirical indicators indicated a significant difference between the measured values and the tabular values. This suggests a distinct contrast in the ability to reproduce hand positions between children with normotypical psychophysical development and older preschoolers with speech disorders. The

p-value indicates statistical significance in favor of normotypical development. Additionally, the statistical outcomes illustrated that children with normotypical psychophysical development excelled in reproducing the position of both hands compared to older preschoolers with speech disorders. The observed trends indicated a notable difference between the two groups. The approximate indicators of normotypical development were higher, while the results for children with speech disorders were comparatively lower. These patterns were evident in children with stuttering and dyslalia, with even lower results seen in those with rhinolalia and dysarthria (Table 3).

Upon investigating subject praxis for the task ‘Performing actions with items,’ the statistical indicators revealed significant findings. The empirical indicators pointed to a substantial difference between the measured values and the tabular values, underscoring an evident contrast in the performance of older preschool children with normotypical psychophysical development and their peers with logopathology. The determined significance level (p-value) underscores the statistical importance of these findings.

Furthermore, the outcomes indicated that older preschool children with normotypical psychophysical

**Table 2.** Results of manual kinesthetic praxis by task “Fine motility of fingers”.

Group	$t_{em}$	$t_{tab}$	p-value	SED	M ± SD
Normotypical development	4.5673	1.964	< 0.0001	0.032	1.8 ± 0.3
Dyslalia	4.9393	1.965	< 0.0001	0.074	1.4 ± 0.7
Stuttering	3.9267	1.965	< 0.0001	0.103	1.4 ± 0.7
Rhinolalia	7.2255	1.969	< 0.0001	0.109	1.0 ± 0.6
Dysarthria	21.7816	1.968	< 0.0001	0.060	0.5 ± 0.5
Children with logopathology	9.8403	1.961	< 0.0001	0.074	1.1 ± 0.7

Clarification of conventional designations:

$t_{em}$  – empirical indicators calculated according to the formula (Student’s t-criteria);

$t_{tab}$  – tabular indicators within the  $p = 0.05$ ;

SED – standard error of the difference, indicates how well the mean represents the sample data;

M ± SD – (M) is the average score; (SD) standard deviation.

**Table 3.** Results of hand kinetic praxis according to the task “Differentiated movements of the hand”.

Group	$t_{em}$	$t_{tab}$	p-value	SED	M ± SD
Normotypical development	11.2250	1.964	< 0.0001	0.045	1.5 ± 0.5
Dyslalia	2.9584	1.965	< 0.0034	0.082	1.2 ± 0.7
Stuttering	1.9077	1.965	< 0.0583	0.129	1.2 ± 0.7
Rhinolalia	4.3641	1.969	< 0.0001	0.146	0.8 ± 0.6
Dysarthria	14.3294	1.968	< 0.0001	0.073	0.4 ± 0.5
Children with logopathology	7.3290	1.961	< 0.0001	0.075	0.9 ± 0.7

Clarification of conventional designations:

$t_{em}$  – empirical indicators calculated according to the formula (Student’s t-criteria);

$t_{tab}$  – tabular indicators within the  $p = 0.05$ ;

SED – standard error of the difference, indicates how well the mean represents the sample data.

M ± SD – (M) is the average score; (SD) standard deviation.

development outperformed their counterparts with logopathology in the task of performing actions with items. The trends observed reflected a notable distinction between the two groups. The average results for children with normotypical development were significantly higher, while those for children with logopathology were comparatively lower. Specifically, the observed distinctions were most pronounced in children with dyslalia, stuttering, rhinolalia, and dysarthria (Table 4).

The comprehensive analysis of the study reveals distinct patterns within the participant groups. Among older preschool children with normotypical psychophysical development, a significant percentage displayed a high level of neuromotor functionality. This was characterized by their ability to accurately reproduce finger and hand positions, successfully complete tasks involving mosaic patterns, graphic depictions, and threading necklaces. Similarly, a substantial proportion of children with logopathology also exhibited a high level of neuromotor functionality. For participants with an average level of speech disorders, along with those with typical development, minor difficulties were encountered in reproducing specific finger and hand positions. Challenges were observed in executing smooth transitions between positions and in completing kinetic and practical tasks. Among children with speech disorders, a smaller subset demonstrated a lower level of neuromotor

functionality. Their performance exhibited characteristics such as chaotic finger and hand movements, difficulty in finding correct positions, occasional errors in connecting fingers, and instances of perseveration of previous movements. Notably, these challenges extended to tasks involving objects, often necessitating consistent assistance from teachers. The observed trends underscore the variations in neuromotor functionality across the participant groups, highlighting the distinct responses based on the presence of speech disorders (Table 5).

According to the statistical analysis, older preschoolers with logopathology had insufficiently developed hand praxis compared to normal psychophysical development. The generalized empirical results indicated a significant difference between the measured values and tabular indicators. The greatest deviation is observed in children with dysarthria, who have the most complex speech disorders. A somewhat smaller deviation was found in children with rhinolalia and dyslalia. Preschoolers with stuttering are more prone to indicators of normotypical development.

Since the empirical values are greater than theoretical ones ( $t_{em} 9.4482 > t_{tab} 1.967$ ), accordingly, hypothesis  $H_1$  at the significance level of 5% ( $p = 0.05$ ) is accepted and confirms the differences between the experimental groups. Speech impairment at the level of neuromotor functions is inextricably linked with

**Table 4.** Results of practical activities for the task “Performing actions with items”.

Group	$t_{em}$	$t_{tab}$	p-value	SED	M ± SD
Normotypical development	4.1121	1.964	< 0.0001	0.029	1.8 ± 0.3
Dyslalia	5.2169	1.965	< 0.0001	0.064	1.5 ± 0.6
Stuttering	4.3447	1.965	< 0.0001	0.099	1.4 ± 0.7
Rhinolalia	6.6943	1.969	< 0.0001	0.110	1.1 ± 0.7
Dysarthria	25.6080	1.968	< 0.0001	0.058	0.4 ± 0.4
Children with logopathology	10.3175	1.961	< 0.0001	0.075	1.1 ± 0.8

Clarification of conventional designations:

$t_{em}$  – empirical indicators calculated according to the formula (Student’s t-criteria);

$t_{tab}$  – tabular indicators within the  $p = 0.05$ ;

SED – standard error of the difference, indicates how well the mean represents the sample data.

M ± SD – (M) is the average score; (SD) standard deviation.

**Table 5.** The general level of formation of kinesthetic and kinetic motor praxis.

Group	Level, %			M ± SD
	High	Average	Low	
Normotypical development	85.6	14.1	0	5.2 ± 0.9
Dyslalia	61.3	21.7	17.0	4.2 ± 1.9
Stuttering	60.0	25.0	6.0	4.5 ± 2.1
Rhinolalia	21.4	50.0	28.6	3.1 ± 1.9
Dysarthria	0	54.5	45.5	1.8 ± 1.4
Children with logopathology	44.8	31.4	23.8	3.3 ± 2.1

**Table 6.** Statistical indicators of neuromotor functionality.

Field of study	Empirical value	Normotypical	Dyslalia	Stuttering	Rhinolalia	Dysarthria	General indicator
The kinesthetic and kinetic motor praxis	$t_{em}$	8.7920	4.6942	3.7358	6.9813	20.3145	9.4482
	SED	0.087	0.200	0.290	0.309	0.167	0.202
	p	0.0001	0.0001	0.0003	0.0001	0.0001	0.0001
	M ± SD	5.2±0.9	4.2±1.2	4.1±2.1	3.1±1.9	1.8±1.4	3.3±2.1
Table value (p=0.05)	$t_{tab}$	250	460	288	276	325	605
		1.964	1.965	1.969	1.969	1.968	1.961

Clarification of conventional designations:

$t_{em}$  – empirical indicators calculated according to the formula (Student’s t-criteria);

$t_{tab}$  – tabular indicators within the  $p = 0.05$ ;

SED – standard error of the difference, indicates how well the mean represents the sample data.

M ± SD – (M) is the average score; (SD) standard deviation.

the development of hand praxis. The more difficult the speech disorder, the more difficult it is to carry out motor activity of the hands. In children with logopathology, hand praxis does not correspond to age development and needs additional educational and developmental influence (Table 6).

## Discussion

Scientific studies of scientists prove that the lack of neuromotor functionality, in particular, kinesthetic and kinetic hand praxis in older preschool children with logopathology delays not only physical but also intellectual [6, 10, 11] and speech [7, 16] development. Konoplyasta [11] claimed in her scientific works that under the conditions of favorable development of the child, her sensorimotor activity is harmoniously switched into a hierarchical structure of voluntary activity. The development of the motor organization affects the regulation of mental processes, the emotional and volitional sphere forming its general behavior. Experimental studies of children with rhinolalia proved that sensorimotor motor activity and physical endurance are reduced in most of them (compared to children with normotypical development). A slow pace of psychomotor development is observed, which the author considers as controlled motor actions.

Our study proves that today the problem has not disappeared, and in which cases it worsens, as indicated by the indicators of kinesthetic and kinetic hand praxis in older preschool children with speech pathology. We note that older preschoolers with dyslalia, in some cases with stuttering and rhinolalia, have a high level of neuromotor functionality, whose motor activity is close to children with normotypical psychophysical development. Average and low indicators are mostly observed in respondents with more complex speech and psychophysical development disorders: dysarthria, rhinolalia, and stuttering, and less often with dyslalia.

Children with speech disorders who have a long-term educational and corrective influence develop

according to normotypical development [16]. We prove the specified statement during the study of “Fine motility of fingers”. During the experiment, it was established that a high level of finger praxis belonged to 85.6% (n = 214) of preschoolers with normotypical development and 45.9% (n = 164) with logopathology. The results of this group of children indicated the ability to independently and correctly reproduce the given positions of the fingers, which indicated a sufficiently formed level of their fine motor skills. Older preschoolers who made minor mistakes during the task and sometimes needed stimulating help from the teacher had an average level of formation of kinesthetic finger praxis. It is observed most in 33.1% (n = 118) of children with logopathology and only 14.4% (n = 36) with normotypical development. The children were asked to quickly complete the task by choosing the right position of the fingers, so they often made mistakes: connecting the thumb and index fingers in a ring (they connected the thumb and the index fingers); transitioning from clenched fingers into a fist to a position where the index finger and little finger are stretched forward. Inattention led to an increased number of attempts and help from an adult.

The relationship between language and motor function is complicated and multifaceted [5], as indicated by the low level of research results was observed in 21% (n = 75) of children with logopathology, who had more than two errors and needed constant support from the teacher, in particular. But this level was most characteristic of children with dysarthria (45.5% (n = 214)), who have weakly developed finger praxis; with a neurotic form of stuttering (15% (n = 6)), in which we note the lack of fine motor skills, the need for additional instruction, a visual sample. Preschoolers of this group did not pay attention to their motor errors, all attempts to complete the task had shortcomings: a long search for the position of joining the thumb and index fingers into a ring (they connected different fingers); difficulty moving from the position of

clenched fingers into a fist to the position where the index and little fingers are stretched forward (extending different fingers forward); difficulty switching from the right hand to the left; trying on the built position of the fingers with the teacher's sample; the need for approval and encouragement from an adult for a correctly completed task. Slowness, increased number of execution attempts, inconsistency of motor actions and adult help indicate insufficient attention, and reduced ability of motor activity of finger kinesthetic praxis give grounds to predict problems during mastering motor skills of written speech.

Having uncomplicated speech disorders or their long-term correction allows children to fully perform differentiated motor exercises [10, 11]. The results of the study of the performance of the task "Differentiated hand movements" showed that high scores belonged mostly to children with normotypical development (49.6% (n = 124)) and 31.4% (n = 112) with logopathology. They demonstrated the ability to independently reproduce various movements according to the example of the teacher. Some of them could make mistakes, but they corrected themselves and performed the task correctly. Performed the exercise with errors and had an average level of 42.9% (n = 153) of preschoolers with logopathology and 40.8% (n = 102) of normotypical development. The children did not perform the task clearly and often made mistakes in changing the position of their hands, sometimes they needed the help of an adult in additional demonstration of the task. Insufficiently formed dynamic praxis and a detected low level are observed in preschoolers 20.2%, 40.8% (n = 72) with speech disorders and 9.6% (n = 24) with normotypical development. This group of children had significant difficulties during the task. It was difficult for them to perform different movements with two hands at the same time: the right hand is clenched into a fist, the left hand is turned downward with an open palm (confusion of hands, not dynamic performance); the left hand is clenched into a fist, the right hand is turned downward with an open palm (difficulties when switching to different movement positions); sequential execution of various movements with one hand: the hand is clenched into a fist, the hand is opened with the "rib" down, the hand with the open palm down hits the table (inhibited reorientation of movement from one position to another). Significant problems in the development of dynamic praxis are observed in children with dysarthria and stuttering, who quickly tire of the task; their movements were not rhythmic, there were difficulties when switching from one position to another; they needed stimulating help from the teacher more than other peers.

In order to learn the skills of a child of older preschool age to perform actions with various

objects, we suggest that she complete the sample task: make a pattern from a mosaic; draw a graphic picture; string beads on a thread. High indicators were demonstrated by 88% (n = 220) of children with normotypical psychophysical development and 45.9% (n = 164) with logopathology. Preschoolers correctly assembled mosaic patterns according to the proposed sample, graphically represented the drawing, and strung a necklace on a thread without the help of an adult. Some could make mistakes during the task but corrected them independently. Minor difficulties arose in the second group of children, who had an average level of subject praxis development. 33.9% (n = 121) of preschoolers with logopathology and 12% (n = 30) with typical development tried to complete the task quickly, so they often made mistakes: in the number of mosaic parts for assembling a pattern; in strokes in a graphic picture; in the number of beads. The correct performance of the task depended on stimulating help from the teacher, who often emphasized "Compare your work with the sample. See if everything is done correctly?". Then, the children noticed the flaws in their performance and quickly revised it.

A study by scientists [9] proves that in children aged 8-10 years, the insufficient formation of motor skills is significantly related to verbal working memory, visual-spatial working memory, and reaction inhibition, but not to the control of obstacles. In our opinion, this problem arises much earlier. What the low indicators of the study indicate. Difficulties arose in children of the third group of preschoolers, 20.2% (n = 72) with speech disorders, who, according to the research indicators, had a low level of development of subject praxis. Preschoolers could incorrectly choose the colours or the number of mosaic parts to make a pattern; extra strokes were depicted in the graphic picture, or they were not drawn; beads were missed, and tasks were not performed correctly even with the help of an adult. In children with dysarthria, rapid fatigue was observed, and slowdown in actions. Insufficiently developed fine motor skills caused difficulties in the operational actions of the fingers: holding a pencil (not adjusting the pressure of the pencil, sloppy drawing, not following the contours of the image), stringing beads on a thread, collecting small mosaic parts to assemble a figure. In preschoolers with a neurotic form of stuttering, we note unstable muscle tone, and impaired fine motility of the hands, which leads to persistent errors when performing practical tasks.

In these children, in addition to the underdevelopment of kinetic hand-hand praxis, there is also a violation of the motor activity of oral and articulatory praxis, which affects the development of speech [10, 11]. It is difficult for them to reproduce movements at first glance, so they

make mistakes or do not complete tasks more often than preschoolers with normotypical development. This indicator is mostly characteristic of children with phonetic-phonemic underdevelopment of speech and general underdevelopment of speech [12].

Experimental analysis of research materials makes it clear that there is a close relationship between motor and cognitive skills of children with speech disorders [6, 9]. Scientists draw a parallel between disorders of motor skills, such as rhythmic coordination, control of walking, positions of body parts (arms, legs, head, etc.), catching objects with malformed cognitive skills, such as internal planning (thinking operations), sensory-perceptual recognition [17], memorization of motor and verbal [10], cognitive information [18, 19], implementation of an executive function [20]. Experimental studies allow us to state that the development of motor skills, such as fine motility of the fingers, coordination of movements in rhythm, sequence of movements contribute to the improvement of cognitive skills and self-regulation.

The described experimental results of all categories of children (rhinolalia, dyslalia, stuttering, dysarthria) prove that the problem is still relevant. Children of older preschool age with logopathology need corrective and developmental work, the lack of formation of hand praxis affects the development of grapho-motor skills, which are necessary for mastering written speech [5]. The revealed unformed state of the neuromotor functionality of the cognitive component in older preschoolers with logopathology provides grounds for the introduction of modern educational and developmental methods that would allow for the formation of kinesthetic and kinetic hand skills (development of fine motility of the fingers). This will contribute to increasing the level of neuromotor development of older preschool children and, in the future, their comfortable integration into the conditions of general education.

## Conclusions

Analysis of research results and statistical confirmation proves that a significant percentage of older preschool children with logopathology have an insufficiently formed state of neuromotor functionality of the cognitive component of the psychological component of speech readiness. *Wrist kinesthetic praxis* in preschoolers with logopathology is not sufficiently formed: it is difficult to perform according to the model of certain finger positions (joining of different fingers); problems switching from one finger position to another; difficulty switching from the right hand to the left; slow completion of tasks. *Wrist kinetic praxis* in

preschoolers with speech pathology is not formed, especially in children with dysarthria and some with stuttering; difficulties during simultaneous execution of various movements with two hands: confusion of hands, impaired performance dynamics; problematic or inhibited switching from one motor position to another. Subject praxis of preschoolers with speech disorders (in most children with dysarthria and some with stuttering) develops slowly. In this group of older preschoolers, fine motor skills are not sufficiently developed, there were difficulties in the operational actions of the fingers: holding a pencil while drawing graphic drawings, stringing beads on a thread, and collecting small mosaic parts to assemble a figure.

Improvement of the neuromotor functionality of hand praxis will be ensured by educational and developmental work, which is able to form control over the actions of the bones of the hands in children with logopathology, as well as develop they fine motility of the fingers. The development of neuromotor functionality should include various educational methods. In particular, the visual method: demonstration of sample positions of fingers and hands. Game method: motor finger games ("playing" songs, poems, fairy tales with the fingers), construction games (modeling from dough, plasticine, stacking, work with origami, quilling, appliqués (laying out drawings with threads, cutting, gluing parts from paper and other materials), lego constructors, cubes, lacing wooden toy materials, stringing a necklace on a thread, fastening buttons, sorting cereals, groping for objects in bags). Method of exercises: motor exercises (flexing and extending fingers, alternate and joint movements of the hands, projecting shadows from the bones of the hands); art exercises (drawing with fingers, tracing the outline of images, connecting a picture by numbers), graphic and motor exercises (writing symbols, numbers, letters as directed).

The outlined type of educational and developmental work will form in children of older preschool age the ability to perform and control differentiated hand movements; perform and control hand and finger movements; carry out manipulations with objects; perform graphic and motor tasks. That will allow to prepare children to study in institutions of general secondary education.

## Acknowledgement

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## Conflict of interest

There is no conflict of interest.

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# Assessment of manual dexterity using the grooved pegboard test in secondary school students aged 11–12 years

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

## Abstract

**Background and Study Aim** Understanding and addressing potential variations in hand dexterity among children is essential for educational strategies and interventions aimed at enhancing fine motor skills development in this age group. The study's objective was to assess hand dexterity levels among 11-12 years old secondary school students, considering variables such as gender, grade, and hand preference.

**Material and Methods** Ninety-three students (41 females and 52 males) in grades 5 and 6 of the secondary school. The Grooved Pegboard Test (GPT) (Lafayette Model 32025) was used as a data collection tool to determine the students' performance in hand dexterity (fine motor skills). The Mann-Whitney U-test was used to test for differences between gender, grade, and hand preference in the mean GPT scores.

**Results** Results showed that both female and male 6th graders had better GPT performance in both dominant and non-dominant hands than 5th graders. On the other hand, there were no significant grade differences in GPT performance between dominant and non-dominant hands ( $p > 0.05$ ). There was no difference in GPT performance between 5th and 6th grade ( $p > 0.05$ ). There were no statistical differences between females and males in GPT performance in either the dominant or non-dominant hand ( $p > 0.05$ ).

**Conclusions** Results highlight the importance of considering age-related changes in fine motor skills when developing educational strategies and interventions for children in the 11-12 year age group. Further research may be needed to explore the underlying factors contributing to these variations in hand dexterity.

**Keywords:** fine motor skill, eye-hand coordination, motor control, manipulative dexterity, visual motor coordination

## Introduction

Fine motor skills represent a set of skills associated with a set of similar structures, such as hand-eye coordination, the transformation of a visually perceived object into a motor output, skills involved in writing, and even handwriting [1]. In some studies, the definition of fine motor skills has been expressed as 'small muscle movements requiring close hand-eye coordination [2].

Fine motor skills are also defined as the coordination of small muscle movements and eye-hand coordination, and commonly include tasks that require visual, cognitive, and manual dexterity, such as picking up objects with tweezers, handwriting, or drawing a picture with a pencil [3]. Suggate et al. [4] suggested that the broad description of fine motor skills could be divided into three categories: general fine motor skills (e.g. dressing a doll), graphomotor skills (e.g. the ability to hold a pencil and draw but not write), and handwriting.

Hand-eye coordination; the creation of appropriate motor responses to the visual stimuli received in the mind and body. The harmony of all

the movements made as a result of the perception of the eye and the transmission of the stimulus to the brain via sensory nerves. The transmission to the necessary muscles via sensory nerves for the implementation of the plan decided to be made. The ability to integrate the use of eyes and hands by making predictions in following and stopping/catching the object [5, 6].

There are many validated tests to measure fine motor skills and hand dexterity in people with impaired hand function. One of these is the Grooved Pegboard Test (GPT), a standardised test that measures manual dexterity, hand-eye coordination, rapid visual-motor coordination and psychomotor speed [7, 8, 9].

Examining research on the Perdue Pegboard Test reveals several notable studies. Wilcox and Nordstokke [10] studied performance in individuals aged 6-14 years, while Kanj et al. [11] investigated factors associated with motor dexterity on the grooved pegboard test. Fuelscher et al. [12] focused on manual dexterity in both the dominant and non-dominant hand. Clark et al. [13] assessed fine motor skills in 4- and 5-year-old children, and Skogan et al. [9] and Van Wijk and Meintjes [14] conducted studies on age, gender, and education. Wilhelm et al.

[15] and Bryden and Roy [16] explored performance differences in dominant and non-dominant hands, while Scharoun and Bryden [17] investigated hand preference, performance, and hand choice in children. Additionally, Schmidt et al. [18] delved into the influence of handedness and gender.

The literature review shows that there are a number of studies that have examined the performance of school children in hand-eye coordination, a fine motor skill. Concerns have been raised about how well normative data collected four to five decades ago reflect motor performance in today's child and adolescent populations, particularly as measured by the GPT. Comparisons of normative data across age, gender and time have the potential to provide new insights [9]. Skogan et al. [9] also reported that a recurring problem in this area of research is the lack of normative GPT data for children and adolescents under the age of 16. In this respect, the research is considered valuable and could contribute to the literature.

*Purpose of the Study.* The study aimed to assess hand dexterity among secondary school students in grades 5 and 6 and to examine performance differences on the Grooved Pegboard Test based on gender, grade, and hand preference variables. In this context, answers to the following questions were sought 'What are the students' hand-eye coordination ability scores and do the performance scores differ according to gender, grade and hand preference variables?'

## Materials and Methods

### Participants

One school in Istanbul agreed to participate in the study by providing access to de-identified data. Ninety-three (21 females and 26 males from 5th grade and 20 females and 26 males from 6th grade) students (11-12 years old) from the secondary school in Istanbul participated in this study, with two classes completing the Grooved Pegboard Test. Thirty-seven of the participants were right-handed and five were left-handed. Class, gender and self-reported handedness were recorded for each participant. The study was conducted in November 2022.

### Research Design

This quantitative study was organised according

to the comparative relational survey model. The study protocol was approved by the Ethics Committee of Marmara University. All participants gave their informed consent and no incentive was given for their participation.

*The Grooved Pegboard Test (Lafayette Model 32025)* was used as a data collection tool to determine the students' performance in hand dexterity (fine motor skills). The Grooved Pegboard Test (Lafayette Model 32025) is a rectangular board with a tray for the 25 pegs and a stopwatch to calculate the time taken to place the pegs in the holes. The stopwatch begins when a subject picks the first peg and ends when the last peg is placed in the hole, at which point the performance time is calculated. Subjects completed two trials, the first with their dominant hand and the second with their non-dominant hand. Hand preference was assessed by declaring their preferred hand for writing. Subjects were instructed to pick up only one pencil at a time, and if a pencil was dropped, to pick up a new one from the pile. Each participant was asked to use their dominant hand to place the pegs in the designated locations. The participant placed the 25 pegs in their correct designated holes in sequential order for each run. The first peg was to be placed in the first left hole in the first row of holes, while the last peg was to be placed in the last right hole in the fifth row of holes. In contrast, for the non-dominant hand, the first pin should be placed in the first right hole in the first hole line and the last pin in the left hole in the last hole line [7].

### Statistical Analysis

Initially, the Grooved Pegboard Test data was entered into Microsoft Excel, meticulously checking for any missing data and inconsistencies to ensure data quality. The data were then coded and analysed using SPSS 22. Normality of the data was assessed using the Shapiro-Wilks test with  $\alpha$  set at 0.05. The Mann-Whitney U-test was used to test for differences between gender, grade, and hand preference in the mean GPT scores.

## Results

The results of this study are presented in the following four tables. In Table 1, no statistical difference was observed in the preferred hand for the Grooved Pegboard Test performance between the sexes in grade 5 and grade 6.

No statistical difference was observed between

**Table 1.** Preferred hand performance across grades

Variable	Grade	Gender	N	Mean (SD)	U	z	p
Preferred Hand	5	Female	21	76.80 (15.38)	219.500	-1.146	.252
		Male	26	80.07 (13.89)			
The Grooved Pegboard Test (second/s)	6	Female	20	70.45 (9.08)	204.000	-1.243	.214
		Male	26	75.76 (12.40)			

\*p<0.05

**Table 2.** Non-preferred hand performance across grades

Variable	Grade	Gender	N	Mean (SD)	U	z	p
Non-preferred Hand	5	Female	21	90.00 (35.15)	266.500	-.139	.889
		Male	26	86.53 (17.31)			
The Grooved Pegboard Test (second/s)	6	Female	20	86.65 (19.98)	211.000	-1.087	.277
		Male	26	82.65 (18.33)			

\*p<0.05

**Table 4.** Non-preferred hand performance across gender

Variable	Gender	Grade	N	Mean (SD)	U	z	p
Non-preferred Hand	Female	5	6	90.00 (35.15)	209.000	-.026	.979
		6	10	86.65 (19.98)			
The Grooved Pegboard Test (second/s)	Male	5	12	86.53 (17.31)	271.000	-1.227	.220
		6	14	82.65 (18.33)			

\*p<0.05

**Table 3.** Preferred hand performance across gender

Variable	Gender	Grade	N	Mean (SD)	U	z	p
Preferred Hand	Female	5	6	76.80 (15.38)	158.500	-1.345	.179
		6	10	70.45 (9.08)			
The Grooved Pegboard Test (second/s)	Male	5	12	80.07 (13.89)	271.500	-1.218	.223
		6	14	75.76 (12.40)			

\*p<0.05

the sexes in terms of non-preferred hand Grooved Pegboard Test (GPT) execution time for both 5th and 6th-grade students (Table 2).

In Table 3, there were no statistically significant differences observed between grades in preferred hand Grooved Pegboard Test (GPT) execution time for both females and males (p>0.05).

There was no statistical difference in the non-preferred hand Grooved Pegboard Test execution time between the grades in females (p>0.05) and males (p>0.05).

## Discussion

The aim of this study was to determine the performance levels of hand-eye coordination (hand dexterity), which is a fine motor skill, in 5th and 6th grade secondary school students, and also to investigate whether there is a difference in these performance levels in terms of gender, grade/class and hand preference variables.

Several studies have shown that GPT performance also depends on socio-demographic variables such as age, gender, handedness and education [10, 12, 17, 19, 20, 21]. Our results showed that both female and male 6th grade students had better GPT performance in both dominant, and non-dominant hands than 5th grade students. On the other hand, there were no significant grade differences in GPT performance between dominant, and non-dominant hands (p>0.05). According to Wilcox and Nordstokke

[10], performance improved across age groups (6-14) for both males and females, Kanj et al. [11] showed that speed of completion of the GPT improved with age. The work of Fuelscher et al. [12] shows age-related improvements in manual dexterity for both the dominant and non-dominant hand. İri et al. [5] reported that there was no statistically significant difference between the sexes in hand-eye coordination in children aged 11-14 years. Ferrett et al. [19] reported that age has a significant effect on GPT performance and is one of the most important factors contributing to completion time. Strauss et al. [21] found that improvement on the Grooved Pegboard Test continues up to the age of 14-15 years.

Our results showed that there was no difference in GPT performance between grade 5 and grade 6. However, females and males in grade 6 had better GPT performance than those in grade 5. As in other studies, our study consistently showed that age has a significant effect on GPT completion time performance and that GPT performance also improves with increasing age.

Previous literature has also shown that fine motor skills are a strong predictor of academic performance [22, 23, 24]. Our findings may also be related to academic achievement as well as age. Skogan et al. [9] noted that studies of children and adolescents reporting gender-specific GPT scores of typically developing children and adolescents

are scarce. Studies have also failed to provide clear evidence of gender differences in manual dexterity performance [3, 21, 25]. Skogan et al. [9] found that males were faster than females with both dominant hands at the age of 10-12 years; Rosselli et al. [25] found that boys were faster than girls (6-11 years) at tapping in manual dexterity tests.

According to our study results, there were no statistical differences between the sexes in GPT performance in both dominant, and non-dominant hands. However, females in grades 5 and 6 performed better on the GPT than males in grades 5 and 6. Our results for GPT performance do not confirm the findings of the above studies.

From a neurobiological perspective, improved manual dexterity in childhood is often attributed to maturation of the corticospinal tract (CST), the sensorimotor white matter pathway responsible for voluntary movements [26]. Fuelscher et al. [12] reported that in children aged 9-13 years, greater manual dexterity of the dominant hand was associated with increased fibre cross-section in the CST. They suggest that greater manual dexterity of the dominant hand in late childhood may be associated with enlargement of the contralateral CST during this period. Thompson et al. [27] reported that the interhand-percentage-difference score for individuals was calculated as preferred hand - non-preferred hand ÷ preferred hand. Clark, Shelley & Cwikla [13] found that the fine motor skills of 4- and 5-year-old children, as measured by the Grooved Pegboard Test, were 243.18 seconds with the dominant hand and 271.82 seconds with the non-dominant hand. The intra-manual percentage difference was 11.8% in favour of the dominant hand. According to Wilhelm et al. [15], the mean time for the Grooved Pegboard test in males (age: 26.9±1.6 years) showed a significant difference between the performance of the dominant and non-dominant hand. The results were 61.04±1.67 s for the right hand and 68.15±1.58 s for the left hand. The intra-manual percentage difference was 10.4% in favour of the dominant hand. The work of Fuelscher et al. [12] shows age-related improvements in manual dexterity for both the dominant and non-dominant hand. Skogan et al. [9] also reported that from the age of 10, girls tended to be faster (dominant hand) than boys in GPT performance. At the age of 11-12 years, boys were faster than girls with the non-dominant hand on finger tapping speed (tap count).

In our sample, the typical percentage score differences between the dominant and non-dominant hand were about %8 (6.46 sec) for males in 5th grade, %9 (6.89 sec) for males in 6th grade, and also %13 (13.20 sec) for females in 5th grade, %16 (16.20 sec) for males in 6th grade on GPT performance in favour of the dominant hand. In the results of our study, there were no statistical differences between females and males in GPT performance in both the

dominant and non-dominant hand. On the other hand, although females in grades 5 and 6 had better GPT performance in the dominant hand than males, males in grades 5 and 6 had better GPT performance in the non-dominant hand than females. In this respect, our results were consistent with the study by Skogan et al. [9].

The current study supports that there is no statistically significant difference in age, gender and hand preference on fine motor skills between 5th and 6th grade boys and girls.

The study findings also show that GPT performance improves with increasing age, females had better performance than males, and females had better in dominant hand than males, in non-dominant hand, males had better than females.

## Conclusions

The results of the present study provide valuable insights into the fine motor skills of 11-12-year-old children and their potential variations based on grade, gender, and hand preference. However, it's important to acknowledge several limitations that should be considered when interpreting these findings.

Firstly, the study's sample size was relatively small, which may limit the generalizability of the results. This small sample size could give the study the character of a pilot study on fine motor skills in children. Future research endeavors should aim to address this limitation by analyzing larger samples and including a broader range of age groups. This would allow for a more comprehensive understanding of the development of fine motor skills across childhood and adolescence.

Additionally, while this study focused on specific variables such as grade, gender, and hand preference, there may be other factors influencing fine motor skills that were not considered in this research. Future studies could explore a wider range of variables to provide a more holistic understanding of the factors contributing to fine motor skill development in children.

## Conflict of interest

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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## The impact of chronotype on $VO_2$ max in university students at two different times of the day

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### Abstract

**Background and Study Aim** To choose the ideal training or performance times, it is crucial to assess  $VO_2$  max performance across different time-of-day particular chronotypes. This study aimed to investigate the differences in  $VO_2$  max between the chronotype of university students during the morning and evening time of the day.

**Material and Methods** Fifty-two university students (26 morning type and 26 evening type) with mean age  $23.05 \pm 2.07$  years, weight  $66.71 \pm 4.31$  Kg and height of  $170.90 \pm 5.18$  cm and BMI of  $22.75 \pm 1.91$  kg/m<sup>2</sup> were recruited based on the results of the Horne-Ostberg Morningness- Eveningness Questionnaire (MEQs) participated in this Cross-over study.  $VO_2$  max was measured directly by gas collected using mouth tube breath to breath through the use of the gas analyzer the AD instrument (model-ML206) with an incremental graded maximal exercise test done on the treadmill.

**Results** The morning type group's  $VO_2$  max was significantly better in the morning hour than it was in the evening ( $p=.013$ ), and when the  $VO_2$  max of the evening type group was measured in the morning and evening hours and compared, there was a statistically significant difference in favour of the evening hours ( $p=.004$ ). Additionally, there is no discernible difference between the  $VO_2$  max of the morning type and the evening type group either in the morning hours or the evening hours, but trends indicate that the morning type group has a higher  $VO_2$  max in the morning hour and the same is true for the evening type group in the evening hour.

**Conclusions** The findings of this study showed an interaction between chronotype and time of the day in  $VO_2$  max. For endurance training, trainers should consider the individual's chronotype and time of the day for exercise prescription.

**Keywords:** chronotype,  $VO_2$  max, morning type, evening type, morningness-eveningness questionnaire

### Introduction

Chronotype refers to an individual's preferred timing of sleep and wakefulness, which can be categorized as morning types, evening types, or intermediate types [1]. The highest amount of oxygen a person can take during maximum exhaustive exercise is called maximal oxygen uptake ( $VO_2$  max), and it stays constant over time despite increasing exercise intensity [2, 3]. Maximal oxygen consumption measures how much oxygen is used by active muscles [4]. It is expressed in absolute units of L/min or relative units of mL/kg/min  $VO_2$  max [5]. One of the most often used metrics in exercise physiology is maximal oxygen uptake ( $VO_2$  max).  $VO_2$  max is the most accurate indicator of young people's aerobic fitness [6] in many sports

and is a prerequisite for peak performance [7]. Clinical research has employed  $VO_2$  max, considered a measure of endurance in various ways [8]. It is a population-wide indicator of cardiovascular disease risk and physical fitness [9].

Due to various bodily situations throughout the day, such as arousal, hunger, jet lag, etc., body responses can sometimes vary. The circadian rhythm is connected to these reactions (i.e. body-clock) [10, 11]. At the same time, the body clock is thought to impact how well people function physically. The results of Chtourou et al. [12] about the impact of the circadian cycle on aerobic activity and maximal oxygen absorption ( $VO_2$  max) were conflicting. Since the 1980s, many studies have studied the impact of the day on endurance exercises. While some studies have indicated that  $VO_2$  max is significantly higher in the morning [13] [14], others have reported that  $VO_2$  max performance

is higher in the afternoon [15, 16]. Morning participants did not raise their  $\text{VO}_2$  max, however evening participants did. Morning participants had a lesser increase in  $\text{VO}_2$  max compared to evening participants [17]. Most studies, including those by [16, 18, 19], revealed that the  $\text{VO}_2$  max is a stable function unaffected by diurnal fluctuations. Hence, it is yet unknown how cardiovascular endurance performance varies during the day with respect to chronotype of individuals.

To our knowledge, none of the previous studies discussed how chronotype affects  $\text{VO}_2$  max in university students at diurnal variation, despite previous studies examining the diurnal influence on collegiate students and adult athletes. In order to choose the ideal training or performance times, it is crucial to assess  $\text{VO}_2$  max performance for university students across different time-of-day particular chronotypes. Therefore this study aimed to examine the relationship between different chronotypes and  $\text{VO}_2$  max in university students during the morning and evening.

## Materials and Methods

### *Participants*

Fifty-two male university students (26-morning type and 26 evening type) with mean age  $23.05 \pm 2.07$  years, weight  $66.71 \pm 4.31$  Kg, height of  $170.90 \pm 5.18$  cm and BMI  $22.75 \pm 1.91$  participated in this cross-sectional study. Subjects who participated in any exercise training during the past three months, suffering from a musculoskeletal injury, have a medical condition that makes exercise dangerous or have a history of or current symptoms of cardiovascular illness (such as angina, shortness of breath, or uncontrolled hypertension) were excluded from study participation. The study was conducted at the Research Lab of Centre for Physiotherapy and Rehabilitation Sciences, Jamia Millia Islamia, and ethical approval was taken from the Institutional Ethics Committee of Jamia Millia Islamia (approval letter no. 18/3/215JMI/IEC/2019). The study was conducted from January 2022 to March 2023.

### *Research Design*

We used Horne and Ostberg Morningness and Eveningness Questionnaires (MEQs), to identify the different chronotype of the individual and MEQs scores ranging from 16 to 86. Scores ranges 42 to 58 imply "intermediate type," while scores between 41 and below imply "evening type." Scores of 59 and above imply morning type [17, 20].

The relative humidity and lab temperature for the tests on the subjects were the same for all the participants. Additionally, subjects were instructed to abstain from heavy meals, coffee, tea, and physical activity at least two hours before the testing. Before beginning the testing procedure, a thorough

medical evaluation and clinical examination were conducted. According to Lehmler et al. [21], anthropometric measurements of age, height, and weight were made, and the (BMI) ranged from 18.5 to 24.9 kg/m<sup>2</sup>; each subject by dividing their weight in kilograms by their height in square meters, the BMI was computed.  $\text{VO}_2$  max was determined by direct method during incremental graded treadmill test. The gas was collected using mouth tube in open circuit using a gas analyzer the instrument AD (model-ML206)  $\text{VO}_2$  max was determined directly breath by breath. The participants in the study underwent a graded maximum exercise test (Telineyhtyma, Kotka, Finland), with the first stage's speed set at 8 km/h for each stage for one minute till exhaustion [22] a on a treadmill. The  $\text{VO}_2$  max was measured at 9-11 am and 4-6 pm for both the chronotype and 48 hours were the washout period for each participant.

Participants were invited to arrive in the morning or two to three hours after their last meal. Before starting, they were given a brief explanation and demonstration of the categorized exercise test protocol. The participants were required to use a mask attached to a device that calculated the total amount of gas exhaled and breathed throughout the test.

All subjects received a session of familiarization and initial instructions on how to walk on a treadmill. The  $\text{O}_2$  and  $\text{CO}_2$  analysis equipment was calibrated in advance of each test. Every 10 seconds, the heart rate and respiratory gas exchanges were averaged. For the graded test, the  $\text{VO}_2$  max matched the  $\text{VO}_2$  max achieved in two consecutive 10-second periods. Participants were deemed to have reached their  $\text{VO}_2$  max if at least three of the following circumstances applied: (a)  $\text{VO}_2$  plateaus despite a faster running pace; (b) a respiratory exchange ratio (RER) of greater than 1.1 at the end; (c) overt indications of fatigue in the individuals; and (d) a heart rate that was within ten beats per minute of the age-predicted maximal HR [23].

### *Statistical Analysis*

The data were reported as mean  $\pm$  SD. The Shapiro-Wilk test was employed to determine whether the data were normal, and the results showed normal distribution. All variables presented a normal distribution in the test ( $p > .05$ ). Paired sample t-test was used to compare the variable according to the time of the day (morning and evening hours) within the group and the variables with chronotype and the time of day were compared using the independent sample t-test (morning time with Morning type and Evening type) and evening time Evening type and Morning type).  $P < .05$  set for significant value. All the analysis was performed by the Statistical Package for the Social Sciences (IBM SPSS) software version 21.0

**Result**

Table 1 showed VO<sub>2</sub> max of same chronotype at two different times of the day and table 2. Showed VO<sub>2</sub> max of two different chronotype at same time of the day.

VO<sub>2</sub> max in the morning time compared to the evening time of the morning chronotype group was significantly better (t=2.66, p= .013 < .05) at 95 % of confidence interval difference. The mean ± SD VO<sub>2</sub> max of morning type in the morning was 41.83± 4.58, and in the evening was 40.41 ± 4.73. When the VO<sub>2</sub> max of the evening chronotype group measured in the morning and evening time was compared a statistically significant difference was found in favor of evening hours (t=-3.20, p=.004 < .05) at 95 % of confidence interval difference. The mean ± SD VO<sub>2</sub> max of evening type in the morning was 41.30± 5.27 and in the evening was 42.90 ± 5.35.

Additionally, there is no discernible difference in VO<sub>2</sub> max of the morning type and evening type group in the morning hours and also evening hours but trends shows morning type group has better VO<sub>2</sub>max in the morning hour and also same for the evening type group has better VO<sub>2</sub> max in the evening hour.

**Discussion**

This study’s objective was to compare the results of two different chronotypes and the time of the day on VO<sub>2</sub> max in university students, which can be used to assess the endurance capacity of the individual. Our finding showed significant differences in the VO<sub>2</sub> max of two chronotypes at two different times

of the day. The morning type has better VO<sub>2</sub> max in the morning and the evening type has better VO<sub>2</sub> max in the evening. Our study is consistent with Carter et al. [14], which observed that the evening type had higher VO<sub>2</sub> max and produced more torque in the late afternoon or evening than in the morning. A study in competitive athletes indicated that morning-type athletes had earlier time-of-day peaks in VO<sub>2</sub>max determined, whereas the peaks of the evening types were later in the day and displayed greater diurnal fluctuation; the bleep test showed less diurnal variation [15].

In addition, there was no significant difference between the two chronotypes at the same time of the day, either in the morning or in the evening on VO<sub>2</sub> max, but the trend indicates morning chronotype had better VO<sub>2</sub> max in the morning as compared to their mean ± SD of morning and evening chronotype while evening chronotype had better VO<sub>2</sub> max in the evening while comparing mean ± SD morning and evening chronotype which is consistent with one study found that there is no effect of chronotype on diurnal variation [26]. The effect of time of day on VO<sub>2</sub> max has revealed that there are linear mixed effects and no significant changes in VO<sub>2</sub> max between different times of the day, no fixed effects of time, and no pairwise comparison of time points reached. The time of day when peak VO<sub>2</sub> max was achieved was approximately equally distributed between 10:00am, 4:00pm, and 9:00pm [27].

Only a few studies have examined responses to physical activity at various times of the day and discovered that diurnal variations are particular to chronotype. For instance, those who slept late had

**Table 1.** VO<sub>2</sub> max of the same chronotype at two different times of the day

Chronotype	Time of the day	Mean ±SD	N	Paired Differences				t - value	P - value
				Mean	Std. deviation	95% CI			
						Lower	Upper		
Morning Type	Morning VO <sub>2</sub> max	41.83± 4.58	26	1.41	2.70				
	Evening VO <sub>2</sub> max	40.41 ± 4.73	26			.32	2.50	2.66	.013*
Evening Type	Morning VO <sub>2</sub> max	41.30± 5.27	26	-1.59	2.54				
	Evening VO <sub>2</sub> max	42.90 ± 5.35	26			-2.62	-.57	-3.20	.004*

NOTE: \* - ????????

**Table 2.** VO<sub>2</sub> max of two different chronotypes at the same time of the day.

Time of the day	Chronotype	Mean ±SD	N	Mean Difference	95% CI		t - value	p - value
					Lower	Upper		
Morning VO <sub>2</sub> max	Morning type	41.83± 4.58	26	.53	-2.22	3.28	.38	.70
	Evening type	41.30± 5.27	26	.53	-2.22	3.28		
Evening VO <sub>2</sub> max	Morning type	40.41 ± 4.73	26	-2.48	-5.29	.33	-1.77	.08
	Evening type	42.90 ± 5.35	26	-2.48	-5.29	.33		

higher  $VO_2$  max levels [24], generated more torque and had higher cerebral and spinal excitability levels [28] in the morning compared to the evening, and morning heart rate recoveries were slower than evening ones [29]. However, the morning people in this investigation displayed no diurnal fluctuation in  $VO_2$  max [24, 28]; nonetheless, spinal excitability increased in the evening, whereas cortical excitability increased in the morning [28]. Exercise in the evening may appear more difficult to morning-type people compared to morning [30]. There is minimal indication that participants' habitual training time influenced the time of day at which they reached their peak  $VO_2$  max since no effect was statistically significant [27].

Only two studies, accounting for chronotype, have examined diurnal variation in directly measured performance (such as time trials) [31, 32]. A survey of 16 college rowers found that morning types performed better in the morning than the evening hour on the 2000-meter ergometer time trial, but neither chronotype nor evening chronotypes showed any diurnal fluctuation in performance [31]. Similarly,

the morning chronotype swam faster in the morning 200 m time trials than neither chronotype did in the evening hours trials among 26 skilled adult swimmers [32]. Considering all of the information, it makes sense to hypothesize that evening chronotypes' circadian typology may favour competition in the afternoon, whereas morning chronotypes may be better adapted to events occurring earlier in the day. However, none of these data indicate whether a certain chronotype performs better than another at a particular time of day, which is consistent with our finding. There are few limitations of this study. The sample size was small. Only male participants were recruited for this study. So this study cannot be generalized to female population.

## Conclusions

Chronotype of the individual affects the  $VO_2$  max of the individual, but there are no significant effects of chronotype at the time of the day on  $VO_2$  max. It is crucial to comprehend the potential effects of performance at specific times of day with distinct chronotypes.

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# The effects of stance width during barbell hip thrust on power and velocity output among adolescent Silat athletes

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

## Abstract

**Background and Study Aim** In the physically demanding combat sport of Silat, strength and power dominate. Consequently, applying various stance widths during barbell hip thrusts may tailor athletes' lower-body exercises to individual needs. This has the potential to optimize performance. The aim of this study is to investigate the impact on performance of power, speed, and stance width among Silat combat athletes.

**Material and Methods** Participants performed 10RM tests in three stance widths: wider than shoulder width (WSW), normal shoulder width (NSW), and narrower than shoulder width (NRW). This was done using a 72-hour counterbalance cross-over study design. Power and velocity were measured and analyzed using a mixed ANOVA design.

**Results** The results indicated a significant main effect of stance width on power ( $F(2,56) = 3.086, p < 0.05$ ) and velocity ( $F(2,56) = 3.683, p < 0.03$ ) output. Both males and females demonstrated the highest power in NRW ( $M = 413.26, SD = 131.76$ ;  $M = 239.53, SD = 111.16$ ), followed by WSW and NSW. A strong positive correlation between power and velocity was observed for all stance widths: WSW ( $r(28) = 0.77, p < 0.001$ ), NSW ( $r(28) = 0.79, p < 0.001$ ), and NRW ( $r(28) = 0.89, p < 0.001$ ). NRW was associated with superior power production, while WSW facilitated higher velocity.

**Conclusions** The results of this study demonstrate the importance of considering a variety of stance width techniques during exercise due to their effects on power and velocity during the barbell hip thrust exercise. Coaches can tailor training programs with a velocity-targeted strength and conditioning approach to enhance performance and competitiveness. Further research should investigate different athlete groups and age levels to refine training methodologies.

**Keywords:** stance width, barbell hip thrust, power, velocity, strength training, Silat

## Introduction

Silat, a traditional martial art from Southeast Asia, typically among Malaysians and Indonesians, is renowned for its diverse and intricate movements encompassing striking and grappling techniques [1, 2, 3]. The physical demands of Silat are multifaceted, requiring skill, agility, muscular power, and endurance. This dynamic and physically demanding art form is an excellent venue for investigating various aspects of athletic performance and biomechanics [4, 5]. In a modern competition format, Silat can further break down into two main categories *Silat Olahraga* (fighting-based) and *Silat Seni* (art-based).

In competitive '*Silat Olahraga*,' *pesilat* (a term for the athlete's Silat) spar with each other, and points are scored based on the execution of techniques [6, 7]. The scoring system typically awards points for attacking and defensive moves, including kicks,

punches, sweeps, and throws. It involves three rounds of sparring, which are 2 minutes per round interspersed with 1-minute rest. Meanwhile, unlike *Silat Olahraga*, a competitive sport version of Silat, '*Silat Seni*' emphasizes aesthetic, artistic, and cultural elements. In *Silat Seni*, *pesilat* performs a series of choreographed movements [8]. The performance usually includes various techniques such as strikes, kicks, and defensive moves, but it also displays the grace and fluidity of the art form. It's pretty similar to forms or kata in Japanese martial arts. The round for each performance is typically around 3 minutes without rest.

As important, strength training has been applied in other combat sports (et., judo, karate, taekwondo) that improves punching force and striking movement [9], as well as reduces the chances of injuries [10, 11]. It played the same role same goes with Silat. This is because, to achieve specificity, similarities should exist between the conditioning session and those required in the field during competition. The dynamic nature of Silat underscores the physical

demand it places on practitioners, encompassing a blend of physical components [2, 4]. In this sense, applying strength training significantly improves overall performance, specifically in Silat. Its effectiveness lies in its capacity to increase strength, power, speed, and endurance, which are fundamental elements in the execution of Silat's diverse techniques, from powerful strikes and kicks to elaborate offensive and defensive maneuvers. Different types of training, approach, and strategies have been applied during a strength training session for the physical demand of Silat.

In the lifting technique during exercise, for example, the stance's width may significantly impact the stability and stress on the spine. For instance, in the sports biomechanics literature, it has been noted that high-force deadlift and squat exercises may affect the kinematics of the trunk and lower extremities and the patterns of muscle coactivation [12, 13, 14]. The biomechanical variety of physical activities can alter joint mechanics and accompanying muscular activity, affecting exercise responses [15].

One frequently utilized lower body limb exercise is the barbell hip thrust (BHT). It is one of the basic technique of exercise that focus on one plane of motion that can be used as one of the protected antecedent movements compared to a more multijoint exercise such as back squat and deadlift. This is crucial for inexperienced athletes or practitioners who may lack the skill or be unfamiliar with hip extension and squatting movement. This is because of the relative simplicity of the activity. As a result, it has been used to increase athletes' speed when running and performance in sports because of the forces produced and the horizontal loads experienced throughout the exercise [16, 17, 18]. It is generally acknowledged that the barbell hip thrust exercise is a risk-free way to build strength over the hip extension range of motion. During the entire duration of the movement, there exists muscular tension. Notably, in comparison to alternative workouts aimed at strengthening the hip, this tension reaches its maximum level during the point of lockout. The lockout point characterizes the hip joint as being in a state of utmost neutrality or slight hyperextension [19, 20, 21].

Moreover, BHT also has been studied in force production on sports performance. Muscle activity using Electromyography (EMG) and kinetic were frequently used to measure force production. For example, peak values during kinetic measurement were 24% and 42% more significant in barbell hip thrust and deadlift than in back squats during lumbosacral and hip extension movement on the force platform [22]. This study suggested that barbell hip thrust demonstrated more hip extension and lower back for strength training with a slightly focused knee extension movement. However,

force production also can be explained using other methods, such as surface electromyography (EMG). One study has shown more strength in hip extension during deadlift compared to barbell hip thrust indicating more activating muscle at the biceps femoris [23].

Stance width is also one of the elements that strength coaches frequently change and apply when performing lower-body movements. Changes in stance width and foot placement are thought to cause various activation of relevant muscles [24, 25]. Many of these foot placements have also been discovered in gait analysis and balance exercises, recovery, rehabilitation, and the workplace [25, 26, 27]. Several other studies have explored the contributions of stance leg muscle spindle afference to the planning of mediolateral foot placement for balance control [28, 29, 30].

Researchers have explored the effects of foot placement on gait analysis, rehabilitation programs, biomechanics, and muscle activity during dynamic tasks within a sport setting [31, 32, 33, 34, 35]. Additionally, some studies have assessed the impact of nonleading foot placement on power and velocity [36, 37, 38, 39, 40]. Nevertheless, there is a substantial understudied aspect of the effect of different stance widths on power and velocity to improve sports performance.

In recent times, a growing body of research has examined the variations in stance width and foot position. In a three-repetition maximum back squat, Larsen et al. [12] explored the effects of stance width and barbell placement on the biomechanic aspects and myoelectric activity in the sticking region. The findings indicated that a higher bar placement was significantly correlated with increased activation in the hip region. In contrast, a lower bar placement was shown to be more strongly connected with activation in the knee region. In a related investigation, the researchers employed a motion capture system to assess three-dimensional kinematics, a force platform to measure ground reaction forces (GRF), and musculoskeletal modeling to estimate muscle forces. In the second experiment, it was observed that the peak power exhibited a considerable increase in the narrow condition. Conversely, both trials demonstrated that the medial ground reaction force (GRF) impulse significantly increased the wide stance. The results of experiment two demonstrated a considerable increase in quadriceps forces under the narrow condition. Additionally, both trials revealed a significant enhancement in posterior-chain muscle forces with a wide stance width [41]. With this information, the effect of back squats, other variations, and various feet and bar placement has been intensively investigated on sports performance.

Over the past decade, the barbell hip thrust (BHT) has gained substantial momentum as a widely used

method of resistance training among recreational and professional athletes specializing in strength and power development. Kinetic, kinematic, and surface electromyography were frequently used to measure force production during exercises. A noticeable difference exists between these approaches utilized to analyse power and velocity performance. Nonetheless, there is scarce evidence on how this foot positioning during stance width affects barbell hip thrusts and other lower body exercises in strength and conditioning settings and power and velocity outputs.

Therefore, this study aimed:

1) to examine the effects of different stance widths (Wider than shoulder width, *WSW*; Normal shoulder width, *NSW*; and Narrow than shoulder width, *NRW*) on power and velocity;

2) to compare male vs. female during power and velocity output;

3) to understand the relationship between power and velocity output during BHT performance in adolescent Silat athletes.

It was hypothesized that there would be no significant difference between the three-stance width on power, velocity production, and gender, and there would be no relationship between power and velocity across the different types of stance width.

## Materials and Methods

### Participants

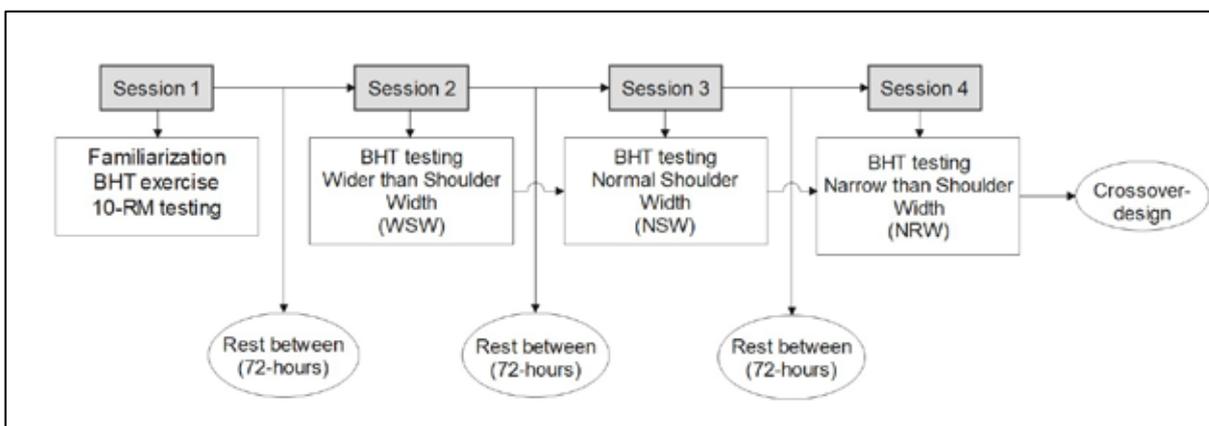
A total of 30 (15 male and 15 female) Silat athletes were involved in this study. The mean age of the Silat athletes was 16 y/s ( $\pm 0.94$ ), weight 36 kg ( $\pm 17.6$ ), and height 147 cm ( $\pm 9.7$ ). The inclusion criterion for the potential participant included (1) at least three years of experience with resistance training; (2) 3 years' of Silat experience; (3) none of the athletes had an injury or illness during the experiment. Written informed consent was obtained from all participants before the commencement of the study, following a detailed explanation of

the experimental protocol, associated risks, and potential benefits of participation.

### Research Design (fig. 1)

The research was conducted throughout four sessions, with a 72-hour gap between each testing day. The participant participated in a familiarization session (Session 1) to familiarize themselves with the experimental protocols. During the same assessment, the researchers evaluated the one repetition maximum (1RM) for the bench press exercise to determine the participants' ten-repetition maximum (10RM) [42]. After the initial session, participants were randomized cross-over for the rest of the testing session (Session 2 – session 4). All testing sessions were conducted in the same indoor facility and adhered to a standardized schedule from 5:00 pm to 8:00 pm. To mitigate the occurrence of excessive fatigue-induced effects, athletes were provided with instructions to abstain from engaging in strenuous training activities within 24 hours preceding each day of testing. Additionally, athletes were strictly prohibited from partaking in the consumption of illegal stimulants within a 24-hour timeframe prior to the commencement of the testing process.

Before the main execution of the testing day, subjects visited the indoor hall to familiarize themselves with barbell hip thrust. Strength training equipment such as barbells and plates has been set up at the indoor arena to suit the 'Silat' competition's feel. Seventy-two hours following a period of familiarization and strength testing, all participants engaged in the main experimental trial. During the main trial session (Session 2 – Session 4), the subject underwent a 10-minute standardized warm-up, emphasizing warming up musculature associated with lower body parts. Subsequently, three warm-up sets were executed, each including incremental increases in the weight of the barbell. Then, each respective subject completed supplementary sub-maximal repetitions, and individual ten-repetition maximums (10RMs) were



**Figure 1.** Research framework.

determined in accordance with the methodology outlined by Baechle and Earle [42].

#### *Testing procedure*

##### *Strength testing (fig. 2)*

A within-subject randomized and counter balanced repeated measure design was used to analyze the 10-RM strength in barbell hip thrust (BHT). In order to ensure that any observable effect during the main trial was solely attributable to the pre-load stimulation (incrementally loaded warm-up), a standardized 5-minute recovery before 10-RM was established. This was to ensure no carryover effect because of the pre-load stimulus. The subject then performed 15- repetitions at approximately 50% of 10RM followed by 12 repetitions at 70% 10RM, and the subject will be asked to lift and stop the loaded that was roughly estimated as their 10RM load based on Baechle and Earle [42] repetition maximum procedures. The logic is that because subjects were young athletes and 10RM strength testing was suitable for their level based on safety purposes.

During the execution of the barbell hip thrust exercise, participants were instructed to consistently elevate the barbell to a predetermined height in each trial. Additionally, they were provided with continuous feedback to ensure no tilting of the barbell at its highest point. The one repetition maximum (1RM) was measured as the maximum amount of weight lifted until the individual could not achieve the barbell's peak height during the concentric phase. Participants were instructed to position their upper back on a bench. The barbell was positioned at the crease of their hips, and a barbell pad was used to minimize any potential discomfort. Participants were provided with instructions to stretch their bodies via the hips, ensuring that their feet remained securely grounded.

##### *Stance width (table 1)*

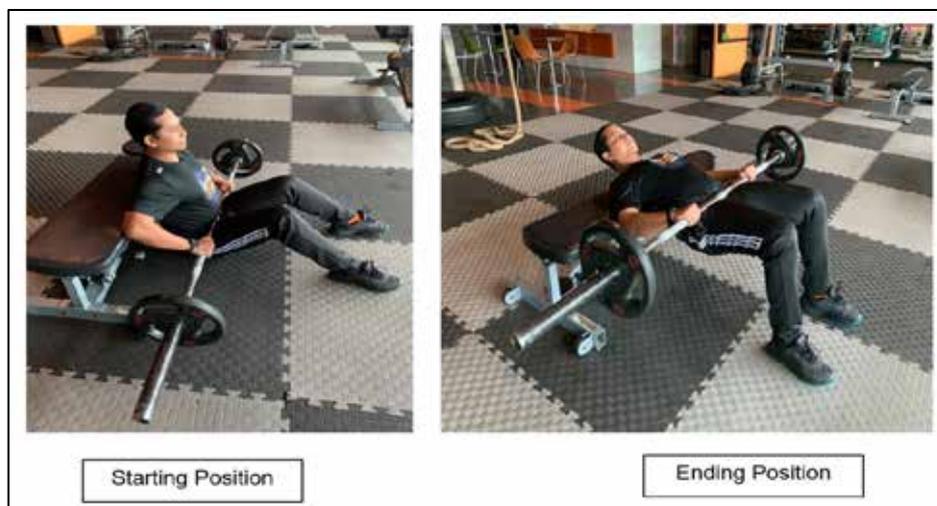
Three different stands were measured in this study (Wider than shoulder width (WSW), Normal shoulder width (NSW), and Narrow than shoulder width (NRW). Subjects were cross-over, randomized, and assigned according to the difference in stance width. For wider than shoulder width, subjects will put their feet approximately 10cm outside from the acromioclavicular joint with the toes pointing forward. Meanwhile, the subject will put their feet approximately 10cm inside the body from the acromioclavicular joint for the narrow stance width. Lastly, with normal shoulder width, the feet will be standing directly the same with the shoulder width in line with the acromioclavicular joint.

##### *Power and Velocity*

In the barbell hip thrust exercise context, the mean concentric bar velocity was measured by utilizing a FLEX device positioned on the right-hand side of an Olympic barbell (Eleiko Performance Weightlifting Bar, Sweden). A reflective marker was affixed to the middle of the device, oriented outwardly. A reflective mat was employed throughout both workout sessions to measure force displacement. This mat was positioned precisely beneath the barbell, ensuring all repetitions were closely observed and recorded. Subsequently, the device was linked via Bluetooth to an iPad (iPad Pro; Apple, Inc., Cupertino, CA) that operated the FLEX Stronger app (Kinetic, Canberra, Australia; firmware version: A714). This app exhibited all the recorded data. The performance measures of the FLEX will utilize power and velocity output [43, 44].

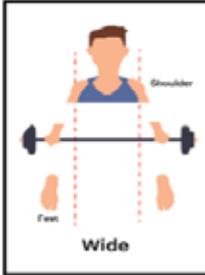
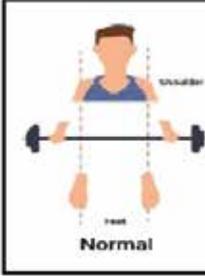
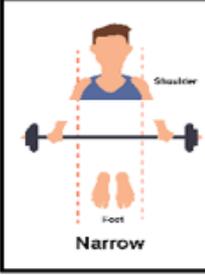
##### *Statistical Analysis*

Statistical analysis used Statistical Packaging for Social Sciences (SPSS) Statistics version 25. Mixed design ANOVA was used to assess the differences in stance width between Wider than shoulder width



**Figure 2.** Barbell hip thrust technique.

**Table 1.** Type of stance width

Position	Stance Width	Feet placement
Wider than shoulder width (WSW)	Approximately 10cm outside the acromioclavicular joint	
Normal shoulder width (NSW)	Directly in line with the acromioclavicular joint	
Narrow than shoulder width (NRW)	Approximately 10cm inside towards the body from the acromioclavicular joint	

(WSW), Normal shoulder width (NSW), and Narrow than shoulder width (NRW). Descriptive statistics (mean ± SD) were used to report the demographic data of the study. The statistical significance level was accepted at  $p < 0.05$ . Mauchly's test was used to assess sphericity, and if not violated, Sphericity-assumed was applied to the result ANOVA. Pearson correlation analyses were also run at each stance width for power and velocity output during the BHT execution.

**Results**

Detailed characteristics of the examined groups can be found in Table 2.

**Table 2.** Physical characteristic and training experiences.

Demographics and Anthropometric	M	SD
Age (years)	16	2.2
Weight (kg)	36	17.6
Height (cm)	147	9.7
Silat (years)	2	2.4
Strength Training (years)	2	1.9

Values are expressed as means ± standard deviations.

*Power output*

From Table 3, this study showed there was a

significant main effect on the type of stance width on power,  $F(2,56) = 3.086, p < .05$  and velocity,  $F(2,56) = 3.683, p < .03$ . For power production, males showed the highest power with NRW ( $M = 413.26, SD = 131.76$ ), followed by WSW with ( $M = 374.33, SD = 131.96$ ) and NSW with ( $M = 363.06, SD = 161.86$ ) in that particular order. For females, the NRW also produced the highest power ( $M = 239.53, SD = 111.16$ ), followed by the WSW ( $M = 213.00, SD = 112.61$ ) and the NSW ( $M = 189.40, SD = 98.58$ ). Bonferroni adjustment has been used to investigate the differences between stance width further. The result showed a significant main effect that reflects a significant difference ( $p < .04$ ) between NRW and NSW. However, there is no significant difference between NRW and WSW and WSW and NSW ( $p > .51$ ). This suggests that the narrow stance may be more effective for power production during barbell hip thrusts for male and female Silat athletes.

*Velocity output*

The mean velocity production was also calculated, and there were significant differences in the three stance widths. For males, the NSW produced the fastest velocity ( $M = .42, SD = .13$ ), followed by WSW ( $M = .43, SD = .10$ ) and the NRW ( $M = .45, SD = .12$ ). Meanwhile, for females, NSW also showed the fastest velocity production during BHT ( $M = .27, SD = .04$ ), followed by WSW ( $M = .28, SD = .05$ )

and lastly, NRW with ( $M = .32$ ,  $SD = .11$ ). Velocity's mean data was inversed from the power produced for both genders. The pairwise comparison shows no statistical difference across three types of stance width, with NRW showing a minor level ( $p = .08$ ) towards NSW compared between WSW and NSW ( $p = .09$ ). The test of between-subjects effects shows that there are significant differences in power,  $F(1,28) = 18.35$ ,  $p < .01$  and velocity production,  $F(1,28) = 19.20$ ,  $p < .01$  between males and females. Males generally produced more power and velocity than females across all stance widths, as shown in Table 4.

*Relationship between Power and Velocity*

To evaluate the magnitude and direction of the linear association between power and velocity across various stance widths, a bivariate Pearson's product-moment correlation coefficient ( $r$ ) was computed. Both variables showed a normal distribution, as determined by the Shapiro-Wilk test ( $p > .05$ ). As per Table 5, this study revealed significant positive correlations between power and velocity during barbell hip thrusts in adolescent

Silat athletes across wide, normal, and narrow stances. Specifically, for the wide stance width (WSW),  $r(28) = .77$ ,  $p < .001$ , indicating a significant association between the two variables. This pattern was also observed in the normal stance width (NSW),  $r(28) = .79$ ,  $p < .001$ , and in the narrow stance width (NRW),  $r(28) = .89$ ,  $p < .001$ . The percentage of variance in power explained by velocity ( $r^2$ ) was approximately 59% for the wide stance, 63% for the normal stance, and 69% for the narrow stance. These findings highlight the strong statistical relationship between power and velocity in all tested stances and suggest the potential for velocity-targeted strength and conditioning programs in Silat training. The analysis demonstrated a statistically significant positive correlation between power output and velocity output during barbell hip thrusts in male and female Silat athletes. These findings underscore the strong relationship between power and velocity in various stances during barbell hip thrust exercises in Silat athletes. Therefore, we can reject the null hypothesis and accept the alternative hypothesis.

**Table 3.** Comparison of power output between Males vs Females.

Power output						
Stance	Male		Female		Sig	$\eta_p^2$
	M	SD	M	SD		
WSW	374.33	131.965	213.00	112.618		
NSW	363.07	161.886	189.40	98.580	.05	.09
NRW	413.27	131.765	239.53	111.166		

Values are expressed as means  $\pm$  standard deviations. WSW = wider than shoulder width, NSW = normal shoulder width, NRW = narrow than shoulder width.

**Table 4.** Comparison of velocity output between Males vs Females.

Velocity output						
Stance	Male		Female		Sig	$\eta_p^2$
	M	SD	M	SD		
WSW	0.43	0.10	0.28	0.06		
NSW	0.42	0.14	0.27	0.05	.03	.12
NRW	0.45	0.12	0.32	0.11		

Values are expressed as means  $\pm$  standard deviations. WSW = wider than shoulder width, NSW = normal shoulder width, NRW = narrow than shoulder width.

**Table 5.** Correlation between power and velocity across all stances.

Stance Width	M	SD	1	2	3	4	5
1. WSW Power	293.67	145.81					
2. NSW Power	276.23	158.57	.790**				
3. NRW Power	326.40	148.84	.639**	.767**			
4. WSW Velocity	0.36	0.12	.766**	.822**	.781**		
5. NSW Velocity	0.35	0.13	.630**	.793**	.748**	.832**	
6. NRW Velocity	0.39	0.13	.565**	.709**	.893**	.758**	.692**

\*\*  $p < 0.01$  level (2-tailed);  $N=30$

## Discussion

The barbell hip thrust enhances lower body strength and power, frequently incorporated into strength conditioning, athletic training, and rehabilitation programs [45, 46, 47]. Like the squat, the barbell hip thrust can stimulate diverse muscle groups by modifying the exercise form and precise stance width [17, 47, 48, 49]. Additionally, studies have conducted a comprehensive biomechanical analysis of the barbell hip thrust [48] and examined differences in the electromyographic activity of lower-body muscles in hip thrust variations [49]. Other research has explored the relationships between vertically and horizontally directed muscle power exercises and top-level sprint performance [51, 52]. Stance width is an important consideration when performing strength training exercises as it can significantly influence the muscle groups worked, the intensity of the exercise, your balance, and overall performance. It has been increasingly acknowledged for its role in modifying the mechanical demands of strength exercises and influencing the distribution of muscular engagement, particularly during lower-body workouts. However, very little information regarding applying a variety of stance widths, specifically during barbell hip thrust and combat sports settings. Hence, the researchers examined the effect of different stance widths on power and velocity output. The findings from this investigation offer valuable insights that could significantly impact the optimization of training protocols in Silat. This martial art requires a delicate balance of power, speed, and agility.

Related to different types of stance width studies, the current study revealed that the NRW was associated with the highest power production in male and female athletes. Even though the main effect for both variables (power and velocity) showed a significant difference, the pairwise comparison statistically showed no differences. Associated with a different type of lower body exercise, this finding aligns with previous research based on Sinclair et al. [53], which found peak power improvement in narrow stance width conditions during 70% of 1RM squats. Twenty males took two distinguished experiments (kinematic and kinetic during a squat) where different stance widths, narrow, mid, and wide, were utilized. The study suggested that performing squats with a narrow stance can enhance the stimulus that is required to facilitate enhancements in sports actions that need high levels of mechanical power generation.

The present study further supports the findings of Larsen et al. [12], which found participants lifting >3 kg greater load during low bar narrow stance compared with other squat movement. The study involved (n=18) men and women who performed squats in two distinguished stance positions, high-

bar narrow stance (HBNS) and low-bar narrow stance (LBNS). They proposed the result greater in HBNS because deeper knee flexion angles provide greater squat depth. In relation to muscular activity, it was shown that the vastus lateralis and gastrocnemius muscles had higher activation levels during the narrow stance than the wide stance.

However, in other types of study, for example, foot placement and angles, Escamilla et al. [54] have indicated that there is no statistically significant difference observed among narrow stance squats (NS), medium stance squats (MS), and wide stance squats (WS). There was 15-16% higher muscle activation on hamstring activity in wide high foot placement (WS-LPH) during squat exercise and more on gastrocnemius in narrow stance in the same exercise. Few studies in barbell hip thrust exercise concur with the result showing that a wide stance much better improves compared to a narrow stance [17, 50, 55]. One thing that needs to be seen here is that most studies involving the barbell hip thrust exercise use a wide stance without considering the difference when performing the exercise. Thus, the current research provides knowledge regarding different stances related to barbell hip thrust exercises.

Our study challenges these notions by proposing that the narrow stance may facilitate greater activation of the quadriceps and hamstring muscles, which are crucial for power generation during the barbell hip thrust. Additionally, a narrower stance may emphasize the adductor muscles of the quadriceps as they stabilize the legs during the movement. This increased activation of multiple muscle groups can contribute to overall strength gains and improved performance in the exercise [12, 56]. This observation has profound implications for strength and conditioning practices in a combat sport setting, specifically in Silat, suggesting that a narrow stance during the barbell hip thrust could potentially enhance power-related performance aspects such as striking force during kicking and takedown strength.

In addition to power production, our study also examined the effect of stance width on velocity production. While the differences in velocity production between the stances did not reach statistical significance, the observed trend suggests that a narrow stance may also be advantageous for maximizing velocity production. This could enhance the speed and agility in Silat's performance, which is crucial for executing rapid strikes and evading opponents' attacks. Future research should investigate this trend and its potential implications for Silat's performance.

Interestingly, our analysis revealed significant gender differences in power and velocity production. Across all stance widths, male athletes generally produced more power and velocity

than female athletes. This could be attributed to physiological differences between the genders, such as muscle mass and strength [57, 58]. However, despite these differences, the narrow stance was the most effective for both genders, indicating its universal applicability. This finding underscores the importance of individualized training protocols considering each athlete's unique physiological characteristics while recognizing the effectiveness of specific universal strategies, such as adopting a narrow stance during the barbell hip thrust [46, 59, 60]. Our study also uncovered an interaction effect between stance width and gender on power and velocity production. This suggests that the influence of stance width on these performance metrics may not be uniform across genders. The specific nature of this interaction effect requires further exploration to understand its implications for training and performance in Silat settings.

The limitation of this study pertains to its narrow focus on evaluating the efficiency of three distinct foot positions without delving into more comprehensive aspects, such as muscular activity. In terms of athletes' involvement in this study, the researcher studied the population of young Silat athletes, and it may have different effects if studied at various other age levels. This study also focused only on Silat athletes. Future research in Silat activities should delve deeper into the disparities in foot position across various age groups and athletic proficiency levels. It is also essential to broaden the scope by examining foot positions in activities targeting different fitness components. The effectiveness of these foot positions during offensive maneuvers in Silat remains a crucial area for exploration. To fully understand the implications, subsequent studies must replicate these findings in broader and more diverse samples of Silat athletes while also investigating the underlying biomechanical mechanisms contributing to the observed effects.

## Conclusions

The results of this study suggest significant contributions in enhancing the efficacy of the barbell hip thrust exercise within the context of Silat athletes. The results suggest that a narrow stance during the barbell hip thrust may be the most effective for maximizing power and potentially velocity production among Silat athletes, regardless of gender. Male athletes generally produced more power and velocity than female athletes across all stance widths, which could be attributed to physiological differences between the genders. However, the narrow stance was the most effective for both genders, indicating its universal applicability. An interaction effect between stance width and gender was also detected, suggesting that the influence of stance width on power and velocity production may not be uniform across genders. These findings have significant implications for designing training programs to enhance performance in Silat, potentially contributing to improved competitive outcomes. Future research should aim to replicate and extend these findings in more extensive and diverse samples of Silat athletes across different groups of ages, levels of athletes, and other types of sports and explore the underlying biomechanical mechanisms and physical performance contributing to the observed effects.

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## Conflict of interest

The authors declare no conflict of interest.

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# Features of planning training loads of coordinating orientation in young female volleyball players aged 10-17, taking into account their age development

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## Abstract

### Background and Study Aim

In the context of youth sports development, it is imperative to emphasize the critical importance of a comprehensive understanding of coordinating orientation training in young female volleyball players. Given the significant variations in physical and neurological growth patterns within this age group, addressing the methodological nuances of tailored training programs becomes paramount. This study aims to substantiate specific methodological approaches for planning coordination training among young female volleyball players, with a keen focus on accommodating the unique intricacies of their developmental journey.

### Material and Methods

Participants in this study included female volleyball players aged 10 (n=25), 11 (n=20), 12 (n=30), and 13 (n=20). The second phase of the study involved the analysis of four years of observations of female volleyball players aged 14 to 17 (n=24), who were carefully selected from a large pool of young candidates. Prior to their participation, both the children and their parents were provided with detailed information about the study, and informed consent was obtained. In the study, a series of tests were utilized, including "Backward Throw to Target", "Stepping over a gymnastics stick", "Running to numbered balls", and "Backward Shuttle Run (3x10 m)". An expert assessment was conducted, involving the participation of highly qualified specialists (n=25).

### Results

The study has demonstrated a substantial increase in coordination abilities among female volleyball players aged 10 to 17. A significant improvement was observed in kinesthetic differentiation abilities (2.3 times). A somewhat smaller increase was noted in their abilities to coordinate and restructure movements and spatial orientation (1.4-1.6 times). The most pronounced and statistically significant improvements were observed in the age group of 10 to 12 years. Changes in volleyball players aged from 12 to 13 and from 13 to 14 in tests assessing the development of spatial orientation and coordination of movements were less apparent. Motor coordination indicators improved significantly in the age group of 14 to 16.

### Conclusions

The identification of age-related characteristics in the development of coordination abilities is crucial for implementing the principle of aligning biological development with pedagogical and training methods. Understanding the various ontogenetic stages is essential for effectively managing the long-term athletic development of young female volleyball players.

**Keywords:** female volleyball players, coordination, abilities, dynamics, development.

## Introduction

The goal of the modern sports education system

in volleyball is to refine a training strategy for producing highly skilled players. This strategy, built on fundamentally new approaches to system development, aims to ensure the sustainable long-term improvement of female volleyball players' sporting achievements. According to Schnabel

[1] and Starosta [2], these approaches place a strong emphasis on the methodological role of the 'technique-coordination' factor. Researchers recommend prioritizing coordination training, defining tasks, means, and methods in accordance with the stages of long-term athletic development.

According to Šimonek [3] and Rathod and Rai [4], the long-term training system for volleyball players should be informed by the age-related characteristics of various types of motor coordination development. This approach allows for the implementation of Bernstein's principle [5], which emphasizes aligning pedagogical influences with the specifics of human biological development. Researchers highlight that the effects of training on young athletes can vary significantly depending on their developmental phase. In certain age stages, motor-oriented training can yield optimal results, while in others, the impact may be more neutral. Only by understanding the nuances of ontogeny periods and adjusting training loads accordingly can we effectively oversee the individual development of young athletes.

To determine the appropriate training load, it is advisable to rely on data related to the age-related development of motor qualities, while considering the concept of 'sensitive periods.' Research examining the age-related development of these qualities has delineated distinct phases characterized by active growth, stabilization, and reduced growth rates [6, 7]. It's noteworthy that sensitive phases extend beyond the development of motor qualities and encompass intellectual, musical, and mathematical domains as well [5].

Within this context, Lyakh et al. [8] introduced a grading system for assessing motor quality development, categorizing it into three levels. Research findings suggest that a growth rate exceeding 3% designates a sensitive period, necessitating the allocation of up to 30% of training time to focus on that specific quality. Qualities with an average growth rate of 2% are recommended to receive 20% of the training time per year. In cases where the growth rate is low, dedicating 10% of training time to address that particular quality is advisable.

The examination of coordinative abilities among schoolchildren in relation to age has been extensively detailed in previous works [7, 9]. Researchers have identified heterochronous development patterns for coordination abilities across different age groups. However it is also valuable to compare age-related dynamics of coordination abilities between schoolchildren who do not participate in sports and young athletes [10]. This comparative analysis not only sheds light on the impact of targeted sports training on the pace of coordinative ability development but also provides essential data for crafting long-term sports training

programs in children's and youth sports schools.

Simonek et al. [11] emphasize the significance of planning and customizing training loads, considering the training potential, for young volleyball players of varying ages, genders, and fitness levels within the coordination training system. According to the authors, the effectiveness of selectively targeted development of motor qualities directly correlates with the specific time period during which they undergo improvement. Researchers identify 'maximum rates of progress' when targeted interventions align with the periods of greatest age-related growth. During periods of submaximal and moderately high progress, a lesser increase in coordination abilities is observed.

Ljach and Witkovski [12] highlight the variability in opinions among different authors regarding the concept of sensitive periods. There remains no unanimous consensus on whether the most significant training effects consistently occur during periods of accelerated development of specific motor skills. What is universally acknowledged, however, is the methodological stance that underscores the importance of accommodating each young athlete's individual pace and development specifics. It is essential for coaches to focus on refining maturing functions within the 'zone of proximal development' [13, 14, 15] rather than attempting to influence already fully matured functions.

However, considering the sensitive developmental stages of coordination skills alone is not sufficient for the successful implementation of young athletes' training processes [16]. The author convincingly argues that it is equally important to incorporate a diverse range of training methods throughout the athletes' development journey. This approach contributes significantly to the formation of robust motor memory among young athletes, facilitating more efficient motor activity restructuring and rapid acquisition of new motor skills. In the author's view, the challenge of planning and normalizing coordination training while accounting for the complexity of training loads remains an area that requires further development.

So, a contradiction arises between the need to determine the age dynamics of the development of coordination skills of young female volleyball players aged from 10 to 17 and, on the basis of this, to develop practical recommendations for improving the training process effectiveness on the one hand and insufficient scientific development of methodological support for solving them educational task on the other hand. This determines the practical and scientific relevance of the research problem.

*Hypothesis.* It is assumed that determining the dynamics of development of those types of coordination skills that play a leading role in ensuring high efficiency of game activity in volleyball will help to optimize the educational and

training process of young female volleyball players aged 10-17. Conducting an expert assessment of the predominant use of certain means of coordination training at different ages will improve the quality of the process of learning motor actions and the effectiveness of their use in changing game situations.

The study aim is to specify some methodological approaches for planning the coordination training of young female volleyball players, taking into account the special features of their age development.

## Materials and Methods

### Participants

Volleyball players aged 10 (n=25), 11 (n=20), 12 (n=30) and 13 (n=20) took part in the experiment. The results of the tests analyzed with the participation of female volleyball players of the above-mentioned age categories were of a “cross-sectional” nature. The second part of the study consists of the results of a four-year observation of female volleyball players aged from 14 to 17 (n=24) who were selected from a large number of young candidates. The children and their parents were informed about all the features of the study and gave their consent to participate in the experiment.

### Research Design

The pedagogical experiment lasted 3 years. Well-known motor tests were used to determine the level of coordination readiness of female volleyball players [8, 17, 18]. As part of the study, the level of development of the abilities for kinesthetic differentiation, spatial orientation, restructuring of motor activity and movement coordination was determined:

Test 1: “Backward Throw to Target” (number of times);

Test 2: “Stepping over a gymnastics stick (s)”;

Test 3: “Running to numbered balls (s)”;

Test 4: “Backward Shuttle Run (3x10 m)” (s).

An expert assessment was the next step of the study. Highly qualified specialists (n=25) took part in the survey. During the training seminar, the

coaches were asked to select, differentiate and group the coordination training means, as well as to determine their proportion depending on the age characteristics of the players.

### Statistical analysis

Statistical data processing was carried out using Microsoft Excel and SPSS programs. The following values were determined for each indicator: arithmetic mean (X), standard deviation (S), standard error (m), assessment of the significance of differences according to the Student’s t-test with the corresponding significance level (p). Differences were considered significant at a significance level of  $p < 0.05$  [19].

## Results

When determining the age dynamics of the development of coordination abilities in young female volleyball players aged from 10 to 17, a statistical discrepancy between the previous and subsequent ontogeny stages was found. In addition to the arithmetic mean of the test results and the standard deviation, the growth rates from one age period to the next one are also given in Tables 1-4. The study showed that female volleyball players between the ages of 10 and 17 show a sharp increase in all indicators of the examined coordination abilities. In particular, there was a significant increase in the indicator characterizing the ability to kinesthetic differentiation (2.3-fold).

A somewhat smaller increase was revealed in the indicators the ability of to coordinate and restructure movements, spatial orientation (1.4-1.6 times). A greater increase in results is noted in tests that are more complex in the coordination sense as age development increases. The assessment of coordination abilities using relatively simple motor tasks does not allow one to “catch” individual changes in the ability to control movements.

The development of individual coordination abilities occurs heterochronously and in different directions. Based on single tests, it is impossible to obtain complete information about the changes taking place in the development of all types of

**Table 1.** Dynamics of the development of movement parameter differentiation ability in young female volleyball players (targeted ball throws)

Age, years	$\bar{X}$	t	p	Increase rate, %
10	7±2.6	-	-	-
11	8.1±1.06	1.23	0.233	15.7
12	10.3±1.9	2.7	0.011	27.2
13	9.9±1.79	1.63	0.138	-4.04
14	10.7±1.25	2.23	0.053	8.08
15	12.42±1.98	2.49	0.025	16.7
16	14.57±1.90	3.20	0.019	17.3
17	16±1.52	2.34	0.058	9.8

**Table 2.** The dynamics of spatial orientation development in young female volleyball players (running to numbered balls)

Age, years	$\bar{X}$	t	p	Increase rate, %
10	17.87±1.34	-	-	-
11	16.96±1.12	1.87	0.075	5.4
12	13.88±1.32	6.43	0.001	23
13	13.20±1.07	1.27	0.219	5.2
14	12.57±0.52	2.20	0.059	5
15	12.23±0.41	1.31	0.24	2.8
16	11.67±0.59	3.65	0.011	4.8
17	11.87±0.81	-0.78	0.465	-1.7

**Table 3.** Dynamics of the development of motor action restructuring ability in young female volleyball players (backward shuttle run, 3x10 m)

Age, years	$\bar{X}$	t	p	Increase rate, %
10	14.53±1,13	-	-	-
11	13.80±1,32	1.41	0.171	5.3
12	12.49±1,34	2.40	0.026	10.5
13	12.04±0,27	1	0.33	3.7
14	11.67±0,44	2.13	0.049	3.2
15	10.82±0,61	3.4	0.003	7.9
16	10.23±0,40	4.09	0.005	5.8
17	10.41±0,59	1.22	0.26	- 1.8

**Table 4.** Dynamics of the development of coordination abilities in young female volleyball players (stepping over a gymnastics stick).

Age, years	$\bar{X}$	t	p	Increase rate, %
10	18.8±4.05	-	-	-
11	16.3±3.9	1.65	0.11	15.34
12	15.1±2.22	0.93	0.36	7.9
13	12.2±1.2	3.98	0.001	23.8
14	12.91±1.84	-1.18	0.25	-5.7
15	12.73±1.2	0.25	0.81	1.4
16	11.67±1.57	0.97	0.370	9.1
17	11.56±1.11	0.197	0.85	0.95

coordination abilities. Generalization of the results obtained allows us to consider the characteristic trends related to the dynamics of the development of these abilities. Characteristically, the most dynamically and statistically significantly studied indicators can be improved in children aged from 10 to 12. Sufficiently dynamic growth in this age range is ensured by exceptionally favorable social, mentally intellectual, anatomical, physiological and motor conditions.

In volleyball players aged 13 to 14, changes in the level of movement control and regulation became less apparent (Table 3). Among volleyball players aged 12 to 13, changes in the development of coordination abilities also became less evident (Table 4).

At this age, there is a certain stabilization and partial deterioration in the development of coordination abilities. Specifically, there was an unreliable improvement in indicators related to the ability to restructure movements and spatial orientation, while the ability to assess spatial-dynamic parameters of movements somewhat deteriorated. These findings are likely associated with puberty. During this period, unfavorable morphofunctional changes occur in the body, leading to disturbances in the ability to control and regulate complex coordination movements.

Our next task was to group the coordination training means and determine their percentage depending on the age characteristics of the players.

**Table 5.** Scheme of ranking the coordination training means for young female volleyball players

Levels, scores	Training means and conditions	Recommended stage (age) of use
10	Double-sided game with special tasks for the players.	Stage of specialized basic training (15-17 years old)
9	2x2 and 3x3 Games-Challenges with One or Two Touches	Stage of specialized basic training (15-17 years old)
8	Attacking different areas of the playing field using single and group blocking	Stages of preliminary and specialized basic training (13-16 years old)
7	Receiving the ball after serving (darkened net is used).	Stage of specialized basic training (15-17 years old)
6	Serving the ball for accuracy (after a previously performed attack)	Stage of preliminary basic training (13-14 years old)
5	Passing the ball for attack (the participant is positioned with his face/back to the direction of the pass)	Stages of preliminary and specialized basic training (13-16 years old)
4	Performing a variety of preparatory and introductory exercises for high-quality mastery of technical elements	Stages of initial and preliminary basic training (10-14 years old)
3	Exercises on the coordination stepladder in combination with the implementation of technical methods of playing volleyball	Stage of preliminary basic training (13-14 years old)
2	Running 6, 9, 12 m from different starting positions and in different ways (side steps, with one's back to the direction of movement)	Stages of initial and preliminary basic training (10-14 years old)
1	Outdoor games, relay races, acrobatic exercises, jumps in various ways.	Initial training stage (10-12 years old)

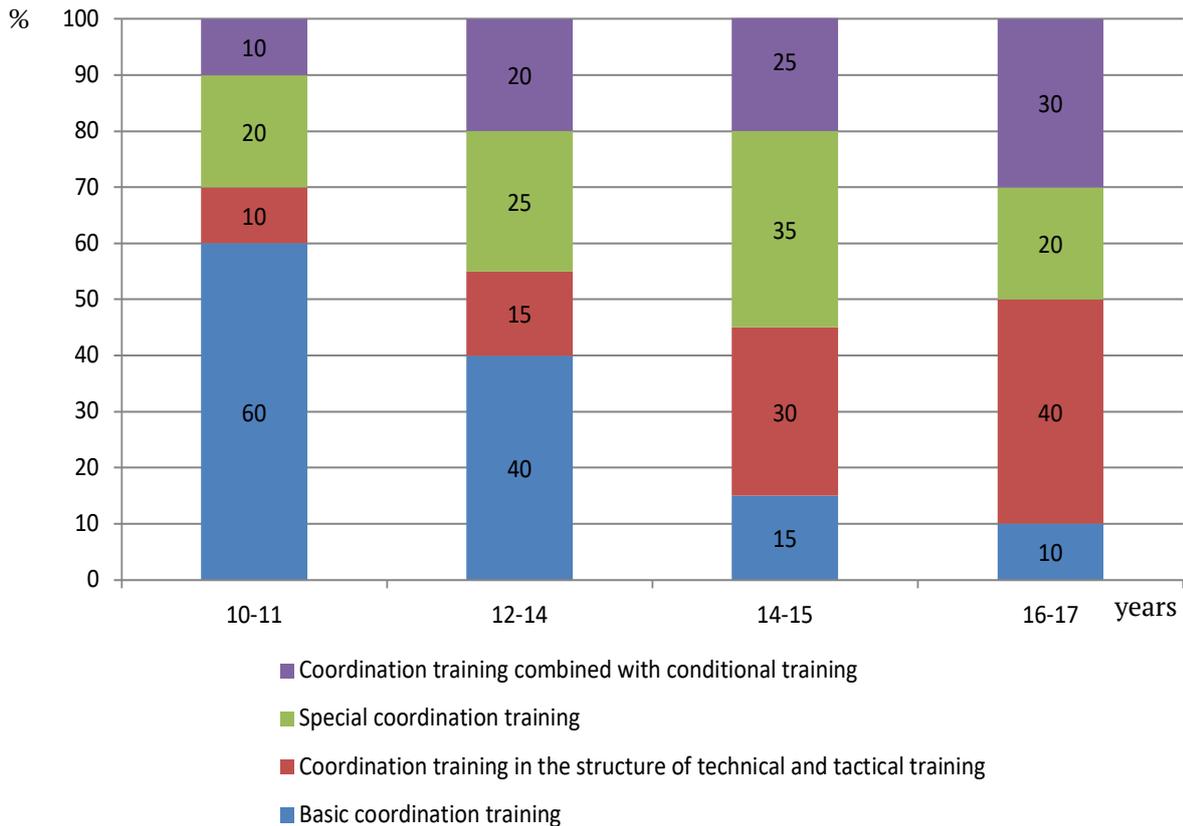
For this purpose, a survey of coaches (n=25) was conducted (Table 5). The study showed that at the stage of initial training, training means are used that have a complex effect on all types of coordination abilities. In particular, these are outdoor games, relay races, running and jumping in various ways. At the stage of preliminary basic training, preparatory and introductory exercises are actively used for quick and high-quality mastery of volleyball techniques. In turn, at the stage of specialized basic training, training means predominate, which require the implementation of techniques in more complex conditions in terms of coordination. The analysis of expert opinions and practical experience made it possible to create a classification scheme for training means of coordination training and their correlation in the process of many years of training (Fig. 1).

## Discussion

The aim of the work was the attempt to specify methodological approaches for planning the process of improving the coordination abilities of female volleyball players, taking into account their age development. After all, studying age-related characteristics of the development of the coordination abilities of young female volleyball players is of paramount importance in optimizing the initial training process. Finally, the natural evolution of the player's body systems has a well-defined sequence and cyclicity. Phases of

accelerated growth are periodically replaced by phases of slow development. It has been studied that the body of a young athlete reacts differently to training means in these phases [20, 21, 22]. The use of training means of the same scope and intensity has a different pedagogical effect and increases the speed of development of one or another motor quality during the period of natural age-related acceleration. There is no doubt that these periods of time are of considerable importance for children and youth sports. The fact is that the motor skills that are not realized at a certain age can sometimes be less fully or not at all achieved at a later age through longer exercises. Experts [23, 24, 25] point out that the temporal boundaries of periods of accelerated development of motor abilities in boys are much wider than in girls and cover almost the entire period of schooling. In girls they are more concentrated in time and, starting from the age of 12, the development of motor qualities is only occasionally characterized by high rates.

When conducting sports selection, sensitive phases shall also be taken into account in order to be able to correctly assess the body states of the participants and the peculiarities of the development of their motor abilities. However, according to [26, 27], when characterizing the age limits of sensitive periods, it is necessary to focus not on the passport but on the biological age of pupils. This is necessary because the acceleration of children and adolescents has expanded the range of individual disagreements,



**Figure 1.** Correlation of coordination training means in the process of many years of sports training of young female volleyball players

where, along with accelerators, retardants are also involved – children who lag behind in growth and body formation at certain stages of ontogeny. As a result, the same passport age unites a contingent of children with different levels of biological maturity.

Given that the physical activity of young athletes is also a condition that stimulates the development of intellectual, emotional and other spheres, the need for scientific development of issues of the educational and training process and physical education of children and adolescents becomes obvious. As a result, in this age period, the development of biomechanical systems of motor actions takes place, which determine the effectiveness and quality of sports, technical and tactical training, as well as morphological and functional transformations that ensure this development [28, 29, 30].

This process (both in the natural and individual age-related evolution of a person, and in sports ontogenesis) proceeds unevenly and is characterized by favorable and unfavorable phases of development of motor qualities that are important for sports performance. A well-balanced system of long-term sports training should provide for the possibility of organizing educational and training influences appropriate to the sensitive periods of age-related development of motor functional parameters and ensuring the success of

the stimulating development of sports equipment and tactical readiness [31, 32, 33].

The study results confirmed the opinion and experimental data of other authors [7, 9] that the studied indicators have two periods with the highest natural increase in results, which shall be taken into account when planning long-term sports training programs for young athletes. It should be taken into account that the authors studied the development of coordination abilities in schoolchildren. It should be noted that the level of these abilities in young female volleyball players is higher than that of their peers who do not play sports systematically. However, the overall dynamic is the same.

If we talk separately about the period of 10-12 years, then the most dynamically and statistically reliable studied indicators improve precisely in this age period. The authors [3, 10, 34], who came to similar conclusions, point out that in the ontogenesis of motor coordination development, the child's maximum ability to develop new motor actions is achieved precisely at this age. Additionally, the researchers argue that at the same time, the body's ability to build muscles and develop the ability to absorb new materials greatly increases. Moreover, it is particularly favorable at this age to develop speed and flexibility. For this reason, this age group is described by many authors as particularly suitable for physical training [35, 36, 37].

At the age of 12 to 13, this is accompanied by a stabilization and partial deterioration of motor coordination in young female volleyball players. These data are fully consistent with the results of other studies showing a strong slowdown in motor function development in girls aged 12–14 years [38, 39]. The authors associate this with the complex morphofunctional restructuring that take place during this age period. During puberty, regressive changes in a number of features of the central nervous system functions are determined. These features reflect not only sensory processes (perception, attention organization), but also central mechanisms of action of motor regulation, including processes of motor activity coordination. However, according to researchers [38, 39], the use of complexes of special coordination exercises in sports training of teenage girls allows not only to prevent deterioration in motor coordination, but also to significantly improve their motor abilities.

If we talk separately about the period from 14 to 15, and especially about the period from 15 to 16, then there is a further improvement in the level of development of the coordination abilities of young female volleyball players. Similar conclusions were drawn [40], which speak of a further significant improvement in coordination abilities in the postpubertal period. According to experts, however, this can only be achieved through the use of a targeted coordination exercise program. Because after 15 years the natural development of most coordinative abilities ends and reaches its maximum. As a result, based on the data presented, it can be argued that after 16 years and later there is another possibility to improve the coordination abilities of young female volleyball players. In particular, if special means and methods of increased coordination complexity are used for this purpose.

An indicative planning of coordination training is presented in the works Lyakh et al. [8]. According to the authors, in order to successfully plan the process of coordination training of young athletes, it is necessary to know the coordination skills that are significant for a particular sport and to select training means for their development. In addition, according to their beliefs, it is necessary to provide exercises for the combined development of significant coordination abilities, as well as speed, strength, endurance, etc. It is important to consider sensitive development phases of coordination abilities.

Based on these recommendations, we conducted a trainer survey.

This survey allowed us to select, differentiate, and group the coordination training means, taking into account their coordination complexity and training potential. The results of the expert assessment confirmed the need to use a wide range of basic coordination exercises at the age of 10–

12 years. These are, in particular, outdoor games, relay races, acrobatics and athletics exercises. This approach makes it possible to create a broad coordination basis for further technical and tactical improvements. In addition, at the age of 15–17 years, coordination training is mainly carried out in combination with technical and tactical training and fitness training [41, 42].

Thus, the results obtained by us allow us to trace the dynamics of the development of coordination abilities of young female volleyball players in the age aspect. The identified periods of greatest increase in certain types of coordination abilities will allow to properly and timely form training effects for maximum progress. A certain percentage of coordination training means in the long-term education and training process, taking into account their coordination complexity and training effect, will help to avoid mistakes in planning this activity. In addition, further research is needed to identify the dynamics of coordination abilities development, taking into account the sex characteristics of those involved. It seems that the time has come to pay more attention to improving the means and methods for controlling the coordination readiness of young volleyball players in order to make the educational and training process more controllable.

## Conclusions

1. Identifying age-related features of the development of coordination abilities makes it possible to implement the principle of unity of biological development and means, methods, forms of pedagogical and training action. Only knowledge of ontogeny periods enables rational management of the process of long-term athletic improvement. The effect of selectively targeted influence on different aspects of motor function is directly related to the period over which they are improved.

1. Analysis of the dynamics of development of coordination abilities of young volleyball players aged from 10 to 17 shows two periods of natural increases in results. The first period is the age from 10 to 12. Favorable social, psycho-intellectual, anatomical-physiological and motor conditions for the rapid development and training of coordination abilities are currently emerging. After that, from 12 to 13, and in some tests from 13 to 14, there is a stabilization and partial decrease in the results conditioned by puberty. At the age of 14 to 16, further improvement in motor coordination indicators continues.
2. When planning coordination training, it is advisable to take into account not only age, gender, but also individual peculiarities of the development of certain coordination abilities of young athletes. It is also important to normalize the training loads according to the degree of

coordination complexity. At the age of 10 to 12, coordination training takes place using a variety of basic coordination exercises. At the age of 13 to 14, many introductory and preparatory exercises are carried out to create a correct

understanding of the elements of volleyball playing technique. At the age of 15 to 17, the coordination training takes place mainly in combination with technical, tactical and fitness training.

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# Determining the influence of dynamic balance in the technical training in football game at U13 level

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

## Abstract

**Background and Study Aim** Technical training in football plays an important part in scoring goals. Precise movements can become the key to victory in a match. Among the principal factors determining the accuracy of shooting or kicking the ball is balance. The study aims to determine the influence of dynamic balance on technical training in U13 football.

**Material and Methods** A group of 26 football players from Otopeni Sports Club (Romania), aged 12-13 years, in the U13 category, participated in this study. Dynamic balance was assessed using the Sensamove MiniBoard platform with tests including: Lateral bipedal balance (LBB), Vertical bipedal balance (VBB), and Vertical unipedal balance for both right (VBRL) and left (VBLL) legs. Technical training was evaluated using tests recommended by the Romanian Football Federation: instep kick from 9 m (Test 1, points), outside kick in 30 sec. (Test 2, points), and 20 m long pass (Test 3, points). Pearson's correlation coefficient was used to analyze the relationship between dynamic balance (lateral and vertical bipedal, and vertical unipedal for both legs) and technical training in U13 footballers.

**Results** The analysis of the comparative results between LBB and VBB variables reveals better performances by 9.2% at VBB. There are lower values of the vertical deviations mean by 2.9 degrees forward at LBB and by -2.8 degrees backward. The mean of lateral deviations is lower by -2.7 degrees to the left at VBB and by 3.3 degrees to the right. The comparative results between VBRL and VBLL variables show better performances by 0.3% at VBRL. The values of the vertical deviations mean are lower by 0.5 degrees forward at VBRL and 0.3 degrees backward. The mean of the lateral deviations (left-right) have equal values. Analyzing the performances obtained in technical tests highlights 22.2% (estimated maximum score) at instep kick, 62.5% (individual maximum value) at outside kick and 34.5% (estimated maximum value) at 20 m long pass. The influence of dynamic balance on technical training shows 60.7% positive connections and 39.3% negative ones between LBB and VBB variables. As for VBRL and VBLL variables, there are 67.9% positive connections and 32.1% negative connections between them.

**Conclusions** The weighting of values at performance and maintaining in space was highlighted. The mean of front-back and left-right deviations in bipedal and unipedal balance has lower values. The technical performances obtained were compared with the estimated maximum score and the individual maximum value. An increased number of positive connections to balance performance variables and of negative connections to the mean of deviations was noticed. This fact contributed to determining the degree of influence on the investigated variables. The findings can serve as a recommendation for future research.

**Keywords:** bipedal balance, unipedal balance, performance, deviation, precision, movement, young, football players

## Introduction

One of the most popular team sports around the

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world is football. All people can enjoy football, starting from children, youth and even parents. During a match, players perform different acyclic movements at different intensities to cope with the complex and dynamic requirements of the competition [1, 2].

Small-sided games (SSG) are a valuable tool for coaches. They help to promote the acquisition of individual and collective behaviors of players for improving overall team performance. It is necessary to compare the technical-tactical knowledge of young footballers in different playing positions during SSG. In this way coaches and players can better understand and predict the actions of each player throughout the game [1, 3]. Identifying how collective tactical behavior varies with age in different playing formats of SSG is also necessary. It can be a useful measure regarding tactical performance in youth football [4, 5]. Many of the actions that take place in football combine a movement (at higher or lower speed) with a jump [6, 7, 8]. SSGs also help to assess skills and talent, as well as to highlight current issues that can guide future efforts [9, 10, 11, 12].

Football is a sport that requires a multitude of technical skills, as well as static, semi-dynamic and dynamic balance. Ball hitting technique or shooting at goal is really important in scoring goals; it can be the key to victory. Balance is one of the main factors in determining the accuracy of ball hitting or shooting. Previous studies made a comparison between plyometric training performed on stable surfaces and the one on unstable surfaces [13, 14, 15]. There were highlighted the effects of these types of training on the components of physical fitness in children and adolescents. Depending on the training modality, specific performance improvements for jumps (stable) and balance (unstable) were identified [16, 17, 18].

Although regularly performed classic football training develops skills, differentiated learning exercises integrated into training programs are more effective for dribbling [19]. Technical skills (first touch, ball kicking, one to one and playing under pressure) are determining aspects in developing youth players. The best ways of implementing the technical training programs for youth must be evaluated for continuous success in football [20]. Dribbling is quite a dominant technique in football training, especially at a young age. Dribbling can be classified into dribbling actions with acceleration and dribbling actions with rapid changes of direction [21]. Physical and technical performance of the player in terms of making successful passes increases as the age increases [22].

The identification of football talent is complex and requires a multiple approach. This one is based on the knowledge of anthropometric, physiological, neuro-motor, cognitive-perceptual and psychosocial variables. In most previous studies, the prognosis confirmation regarding very early talents focused on the later stages of U12 and U15 [11, 23, 24, 25].

The specifics of how excellence is achieved in elite football was repeatedly investigated by many

specialists through various approaches. A growing number of studies analyze tactical behaviors in football, based on the collective movements of teammates. Key-indicators are identified in team sports (such as football, basketball and rugby). Methodological issues related to jump training (plyometric) in football players with different fitness levels are studied [26, 27, 28]. The technical and tactical skills of footballers, as well as their anthropometrical and physiological characteristics are monitored according to age. The advantages of the global approach compared to the analytical approach in acquiring and developing technical skills were analyzed. The integration of physical and tactical variables in football was also studied, using positional data [20, 29, 30, 31].

Currently, an almost routine practice is to include balance exercises in the training programs for athletes in various sports. Most balance research focused on the effects of balance training programs on physical performance and injury prevention. Football is considered a sport using a single leg dominantly and balance skills are really necessary during the game. It involves the performance of multiple actions in a one-legged stance, such as kicking, making a pass and dribbling. The ability to maintain a stable balance position on one leg during fast movements of direction change is fundamental. A good level of agility (both running and reactive) requires speed, dynamic balance, dynamic strength and coordination skills as well [8, 9, 32, 33].

Present trends in attacking strategies and increased workload in modern football entailed the need for fast and well-trained athletes. Obvious improvements in speed, coordination, strength and endurance were observed in elite youth players too [34]. However, there are few studies on the effect of basic training in the development of motor performances in U13 footballers [35].

*Purpose of the Study.* The study purpose was to determine the dynamic balance influence on technical training in football game at U13 level.

## Materials and Methods

### *Participants*

A group of 26 football players participated in this study (U13, mean age  $11.69 \pm 0.8$  years, height  $151.7 \pm 6.7$  cm, weight  $40.9 \pm 7.3$  kg and BMI  $17.7$  kg/m<sup>2</sup>). The participants were selected from the U13 group of the Otopeni Sports Club, Ilfov County, Romania. The consent of the parents was required and signed before starting the research according to the Declaration of Helsinki. It was approved by the Ethics Committee of the Doctoral School of Physical Education and Sport Science (ID: 03/22.07.2023), University of Pitesti, Romania.

### *Research Design*

The research was conducted in February 2023,

for highlighting the influence of dynamic balance upon technical training in U13 football.

In that regard, the Sensamove MiniBoard platform (Nederland) was used to determine the dynamic balance. The tilting angle was 10 degrees and the balance had to be maintained for 16 sec. Tests used:

- a) Lateral and vertical bipedal balance. Parameters used: performance (%), for lateral balance front, inside (%), back, inside (%). For vertical balance left, inside (%), right, inside (%), front, avg. dev. (degree), back, avg. dev. (degree), left, avg. dev. (degree), right, avg. dev. (degree).
- b) Vertical unipedal balance (right and left leg). Parameters used: performance (%), left, inside (%), right, inside (%), front, avg. dev. (degree), back, avg. dev. (degree), left, avg. dev. (degree), right, avg. dev. (degree)

To evaluate the level of technical training, tests recommended by the FRF and selected were used as follows:

*Test 1 – instep kick* from the distance of 9 m. Players had 5 attempts. Shots are done with balls of the same size. The ball must enter the goal in the air (direct aerial trajectory). Players are scored according to the areas marked in the goal: 10 points top left / right; 5 points bottom right/ left; 3 points top center and 1 point bottom center. Estimated maximum score = 50 points. If the junior players hit the ball with other part of the leg or the ball touches the ground before entering the goal, the attempt is not taken into account (failed).

*Test 2 – outside kick.* A 5 / 10 m rectangle is drawn. A gym bench is placed upside down on the 10 m side. The player kicks the ball successively for 30 sec. (outside kicks). The ball is kicked on the 5 m line. If the ball goes over the bench and stops in the net, the player can use the spare ball. If this ball too reaches the goal, the player must recover it and continue the exercise from 5 m line. The player has the right to only one spare ball. The ball can be kicked directly or with taking-over, depending on the abilities of the individual. The number of times the ball hits the bench during 30 sec. is counted. Each player has the right to one attempt and the obtained result is multiplied by 3 points.

*Test 3 - long pass.* The player is at a distance of 20 m from the square made of cones (5x5 m). From this spot, he will make a long pass by instep kick. The ball must have an aerial trajectory until it touches the ground in the marked area. The player has the right to one warm-up attempt and 3 evaluation attempts; each success is marked with 20 points. Estimated maximum value = 60 points.

#### Statistical Analysis

The statistical indicators were calculated using the KyPlot 6.0 (©1997-2020, KyensLab Inc) program, in terms of mean, standard deviation (SD), coefficient

of variation (CV%), Confidence Level of Mean (0.95) and Confidence Limit of Mean. Pearson's correlation coefficient was applied to evaluate the relationship between dynamic (lateral and vertical) bipedal and vertical unipedal (left and right) balance by technical training of the U13 footballers. Statistical significance was set at  $p < 0.05$ .

## Results

The results of the specific motor skills in bipedal and unipedal balance are listed in the tables 1 and 2.

The results of the comparative analysis between the variables of lateral balance (LBB) and vertical balance (VBB) show better performances at VBB by 9.2%, maintaining inside the space by 7.5% between front and left inside and 1.9% between back and right inside. The mean of vertical deviations has lower values at LBB by 2.9 degrees forward and by -2.8 degrees back. The mean of lateral deviations has lower values at VBB by -2.7 degrees to the left and 3.3 degrees to the right. Comparing the Confidence Limit of Mean of the deviations between LBB and VBB, a lower deviation by 0.5 degrees is noticed at VBB. This fact justifies the better vertical balance performance.

The results of the comparative analysis between the variables of right leg vertical balance (VBRL) and left leg vertical balance (VBLL) highlight better performances by 0.3% at VBRL, keeping inside the space by 0.3% left inside at VBLL and 0.8% right inside at VBRL. The mean of vertical deviations has lower values at VBRL by 0.5 degrees forward and 0.3 degrees back. The mean of lateral deviations has equal values both to the left and to the right. Comparing the Confidence Limit of Mean of the deviations between VBRL and VBLL, one can observe a lower deviation by 0.3 degrees at VBRL. Thus, the balance on the right leg has better performance.

The results regarding the technical training of the U13 footballers ( $n=26$ ) are shown in table 3. The scores obtained in each test are highlighted, according to the requirements recommended by the FRF and adapted by us.

The analysis of the performances obtained in *Test 1*, regarding the ball instep kick from 9 m, reveals the total score achieved in the 5 attempts performed. The estimated maximum score highlights a mean of the group of 22.2%. The Confidence Limit of Mean ranges from 16.3% below mean and 15.3% above mean. *Test 2* presents the ball outside kick from a distance of 10 m in 30 sec. The results of the score reveal a mean of 62.5% (individual maximum value of 48 points) and the Confidence Limit of Mean between 11.7% below and above the mean. *Test 3* deals with the 20 m long pass. It has a mean of 34.5% of the estimated maximum value and the Confidence Limit of Mean between 35.3% under mean and 35.7% above mean. Total level training highlights the score obtained

**Table 1.** Results of the specific motor skills in the bipedal lateral and vertical balance at U13 level (n=26)

Tests	Variables	mean ± SD	CV (%)	Confidence Level of Mean (0.95)	Confidence Limit of Mean	
					Lower	Upper
LBB	performance (%)	64.3 ± 14.9	23.1	6.00	58.3	70.3
	front, inside (%)	32.5 ± 10.1	31.0	4.1	28.5	36.6
	back, inside (%)	31.6 ± 11.9	37.8	4.8	26.7	36.4
	front, avg. dev. (degree)	1.91 ± 0.7	35.4	0.27	1.6	2.2
	back, avg. dev. (degree)	-2.4 ± 0.9	-37.0	0.4	-2.7	-2.0
	left, avg. dev. (degree)	-4.6 ± 1.3	-28.8	0.5	-5.1	-4.0
	right, avg. dev. (degree)	5.1 ± 1.6	32.0	0.7	4.4	5.7
VBB	performance (%)	73.5 ± 13.2	17.9	5.3	68.2	78.8
	left, inside (%)	40.0 ± 11.5	28.7	4.6	35.4	44.7
	right, inside (%)	33.5 ± 8.2	24.4	3.3	30.2	36.7
	front, avg. dev. (degree)	4.8 ± 1.1	22.0	0.4	4.3	5.2
	back, avg. dev. (degree)	-5.2 ± 1.5	-29.6	0.6	-5.8	-4.6
	left, avg. dev. (degree)	-1.9 ± 0.7	-36.4	0.3	-2.1	-1.6
	right, avg. dev. (degree)	1.8 ± 0.7	35.4	0.3	1.6	2.2

Note. Values are expressed as means ± standard deviations (SD), CV% – coefficient of variation, avg. – mean, dev. – deviation; LBB - Lateral bipedal balance; VBB - Vertical bipedal balance

**Table 2.** Results the specific motor skills in the unipedal vertical balance of the U13 footballers (n=26)

Tests	Variables	mean ± SD	CV (%)	Confidence Level of Mean (0.95)	Confidence Limit of Mean	
					Lower	Upper
VBRL	performance (%)	84.0 ± 13.9	16.5	5.6	78.4	89.6
	left, inside (%)	41.5 ± 16.4	39.4	6.6	34.9	48.1
	right, inside (%)	42.5 ± 16.4	38.5	6.6	35.9	49.1
	front, avg. dev. (degree)	4.9 ± 1.0	20.3	0.4	4.6	5.4
	back, avg. dev. (degree)	-5.4 ± 1.4	-24.8	0.5	-5.9	-4.9
	left, avg. dev. (degree)	-1.3 ± 0.7	-53.3	0.3	-1.5	-0.9
	right, avg. dev. (degree)	1.2 ± 0.4	34.3	0.2	1.0	1.4
VBLL	performance (%)	83.7 ± 14.0	16.7	5.6	78.1	89.4
	left, inside (%)	41.8 ± 14.1	33.7	5.7	36.1	47.5
	right, inside (%)	41.7 ± 17.2	41.3	6.9	34.7	48.6
	front, avg. dev. (degree)	5.4 ± 1.3	23.5	0.5	4.9	5.9
	back, avg. dev. (degree)	-5.7 ± 1.5	-27.1	0.6	-6.3	-5.1
	left, avg. dev. (degree)	-1.3 ± 0.5	-42.4	0.2	-1.5	-1.1
	right, avg. dev. (degree)	1.2 ± 0.5	44.0	0.2	0.9	1.4

Note. Values are expressed as means ± standard deviations (SD), CV% – coefficient of variation, avg. – mean, dev. – deviation; VBRL - Vertical balance right leg; VBLL - Vertical balance left leg

following the three tests, with a mean of 49.1% of the individual maximum value achieved (126 points). The Confidence Limit of Mean is between 18.5% under mean and 18.4% above mean. From the comparison of the Confidence Limit of Mean, a variation of the range from 15 to 35% under and above the mean is observed.

A Pearson linear correlation analysis was performed for determining the influence of dynamic

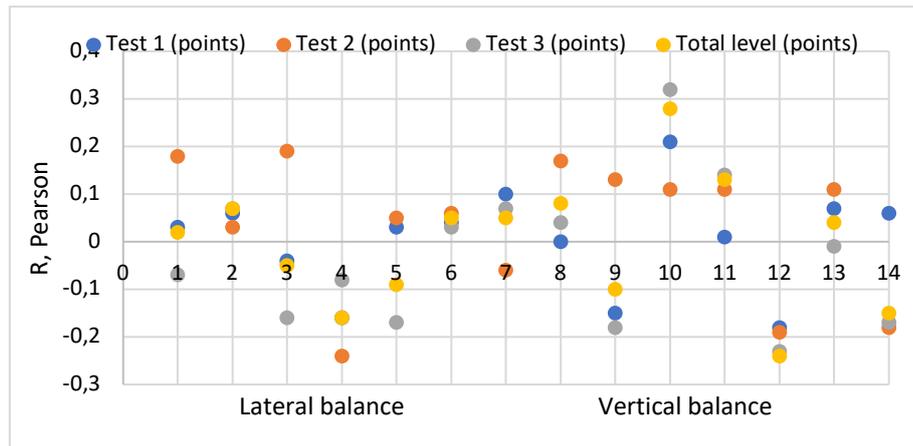
balance on technical training at U13 level. It is shown in figures 1 and 2.

The correlation analysis between the variables of bipedal dynamic balance (lateral and vertical) and technical training highlight 60.7% positive connections and 39.3% negative connections (fig. 1). Regarding the relation between performance and maintaining inside the space (front and back inside) at LBB and the technical training level, one

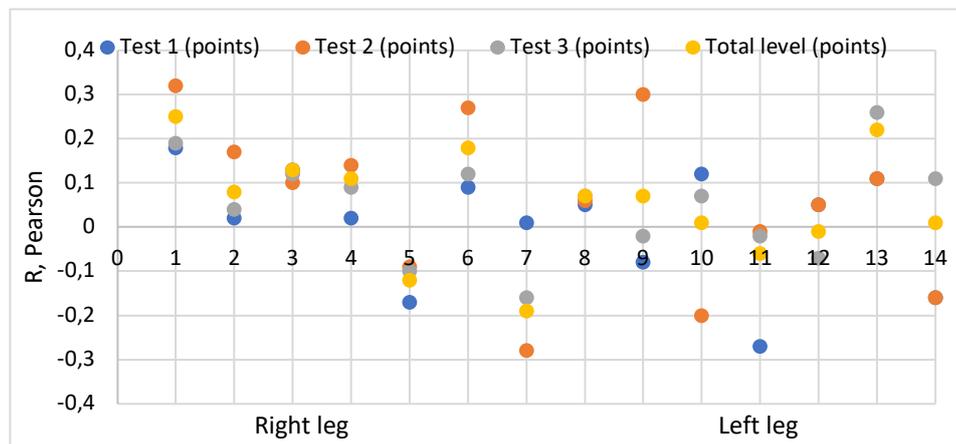
**Table 3.** Results of the technical training of the athletes in football game at U13 level (n=26)

Tests	Variables	mean ± SD	CV (%)	Confidence Level of Mean (0.95)	Confidence Limit of Mean	
					Lower	Upper
Test 1	total 5 exec. (pts)	11.1 ± 2.4	39.7	1.8	9.3	12.8
Test 2	exec. 30 sec (pts)	30.0 ± 8.8	29.4	3.6	26.5	33.6
Test 3	total 3 exec. (pts)	20.7 ± 18.3	88.2	7.4	13.4	28.1
Total level training (pts)		61.9 ± 28.2	45.5	11.4	50.5	73.3

Notes. Values are expressed as means ± standard deviations (SD), CV% – coefficient of variation, avg. – mean, dev. – deviation; pts – points



**Figure 1.** Correlation between dynamic bipedal balance and technical training of the athletes in football game at U13 level (n=26). Note: Lateral bipedal balance indices: 1 - performance (%), 2 - front, inside (%), 3 - back, inside (%), 4 - front, avg. dev. (degree), 5 - back, avg. dev. (degree), 6 - left, avg. dev. (degree), 7 - right, avg. dev. (degree); Vertical Bipedal balance indices: 8 - performance (%), 9 - front, inside (%), 10 - back, inside (%), 11 - front, avg. dev. (degree), 12 - back, avg. dev. (degree), 13 - left, avg. dev. (degree), 14 - right, avg. dev. (degree).



**Figure 2.** Correlation between vertical unipedal balance and technical actions of the athletes in football game at U13 level (n=26). Note: Right leg vertical balance indices: 1 - performance (%), 2 - left, inside (%), 3 - right, inside (%), 4 - front, avg. dev. (degree), 5 - back, avg. dev. (degree), 6 - left, avg. dev. (degree), 7 - right, avg. dev. (degree); Left leg vertical balance indices: 8 - performance (%), 9 - left, inside (%), 10 - right, inside (%), 11 - front, avg. dev. (degree), 12 - back, avg. dev. (degree), 13 - left, avg. dev. (degree), 14 - right, avg. dev. (degree).

can observe 66.7% positive influence and 43.75% negative influence upon the mean of the front-back and left-right deviations. The relation between performance and keeping inside the space (left

and right inside) at VBB and the level of technical training highlights 75% positive influence and 50% negative influence on the mean of the front-back and left-right deviations. The comparison of the

relations between the analyzed variables reveals a better influence at VBB.

The results of the correlation analysis between the variables of the unipedal dynamic balance (right and left leg) and the technical training show 67.9% positive connections and 32.1% negative connections (fig. 2). As for the relation between performance and keeping inside the space (left and right inside) at VBRL and the technical training level, the following aspects are found out. There is a full positive influence and 43.75% negative influence on the mean of the front-back and left-right deviations. The relation between performance and maintaining inside space (left and right inside) at VBLL and the technical training level reveals 75% positive influence and 50% negative influence on the mean of the front-back and left-right deviations. By comparing the relations of the analyzed variables, it shall be noticed a better influence in VBRL at performance. It is also observed a better influence (by 6.25%) at the mean of deviations in VBLL.

Related to the comparison of the relations between the variables of the bipedal and unipedal balance with the technical training level, the following observations are made. There are better performances and maintaining inside the space through positive connections at VBB and VBRL. There are also negative connections (better ones) both at VBB and VBLL. Even if these connections are insignificant, the sense of the relations (positive or negative ones) determines the level of influence of the variables on their performance.

## Discussion

The study aimed at determining the influence of dynamic balance on the technical training in football game at U13, before the development of a training program. In this sense, two tests were used for evaluating the bipedal balance (lateral and vertical) and the unipedal vertical balance on both right and left foot.

The analysis of the comparative results between the LBB and VBB variables highlights better performances by 9.2% in VBB. There are lower values of the mean of vertical deviations forward and backward at LBB. The mean of the left and right deviations at VBB is also shown (Table 1). Comparative results between the VBRL and VBLL variables reveal better performances by 0.3% at VBRL. There are lower values of the mean of front and back deviations at VBRL and equal values of the mean of left and right deviations at both legs (Table 2).

In the specialized literature, dynamic balance performance (DBP) is the ability to maintain adequate postural control. For example, knee stability should be perfect while standing on one leg and performing a specific action with the other leg, such as shooting the ball [36]. Significant main

effects related to balance performance and age have been already highlighted in previous studies. DBP and postural control of the dominant leg showed a significant positive correlation with age in young football players [17, 37]. Other studies highlighted that proper balance ability could lead to higher speed in the case of the younger football players [17, 36, 38]. On the other hand, dynamic balance stability failed to differentiate between faster and slower team athletes [39]. The statistical analysis also shows that balance has a significant contribution to the accuracy of shooting at goal in football. Thus, dynamic balance effectively contributes at 24.28%. These results prove that dynamic balance has almost as much contribution as the variables of leg muscles strength [13]. The plyometric training effects using stable/unstable surfaces were examined in the case of prepubertal footballers as for their physical performance. After 8 weeks of training, similar levels of performance were observed regarding jumping ability, speed, dynamic balance and agility [18]. The associations between multidirectional speed performance, dynamic balance performance and chronological age were also studied in the young football players. The tests used for this purpose could be useful screening tools for detecting performance deficits and implementing preventive training programs [33].

Many studies aimed to demonstrate that Small Sided Games (SSG) is an effective method for developing the ability to repeat sprints. This training program improves recovery capacity before high intensity efforts in young football players. Also, it allows to work on technical and tactical elements and to develop the physical profile of the players. SSGs are widely used to replicate certain technical, tactical or physiological responses. Some constraints were applied to ensure that kicking is given special attention [7, 8]. Relationships between physical and performance characteristics and the skill level were determined in the football players aged 12-16 years. The analyzes highlighted that elite players had better scores than non-elite players regarding strength, flexibility, speed, aerobic endurance and anaerobic capacity [25]. The relative contributions of body size, skeletal age and motor performance variables in young players were also studied during SSGs. The interaction of biological maturation with technical and motor performance was monitored as well. However, as in most other sports, in youth football too the predictive value of such findings is still unclear. Therefore, some specialists evaluated the medium-term prognostic validity of generic motor performance tests [10, 12]. The effects of a differentiated learning program included in SSGs on the creative and tactical behaviour of footballers were identified. This program has been found to have clear effects, demonstrating greater improvements in U13 football players compared to U15 category

[22].

A Pearson linear correlation analysis was performed to determine the influence of dynamic balance on technical training. The results show 60.7% positive connections and 39.3% negative connections between LBB and VBB variables. There are also 67.9% positive connections and 32.1% negative connections between negative connections between VBRL and VBLL variables. Pearson correlation and hierarchical multiple regression were performed to explore the relation between variables in the analysis of balance performance. There were examined the relation between the age of players, body composition, balance and other fitness parameters (strength and flexibility). Generally, no substantial relationship was found between the static and dynamic balance variables. Therefore, it is essential to include both as complementary measures while evaluating the postural balance of young football players [34]. Dribbling ability was carefully studied as well. It is influenced by several factors such as agility, leg-eye coordination and balance. Based on the results, it was recommended that these factors be specially trained. The purpose is to improve dribbling skills of young football players, mainly the 9-12 age group [21]. Another aspect studied by specialists was the goal scoring method: line goal, double goal or central goal. The age-related effects on the defensive performance of U13 football players were also monitored. The moments of ball possession regaining were analyzed using several variables. These variables are: type of ball recovery; sector of ball recovery; configuration of the game; defense status [6].

## Conclusions

The comparative analysis between LBB and VBB variables highlights the share of better performances at VBB. In terms of maintaining inside the space, the comparison was made between front and left inside and between back and right inside. Lower values were observed as for the mean of vertical deviations at LBB forward and backward. The mean of lateral deviations has lower values at VBB to the left and also to the right. The comparison of Confidence Limit of Mean of deviations reveals a smaller deviation at

VBB. This one justifies the better performance at vertical balance.

The results of the comparative analysis between lateral balance variables – right leg (VBRL) and left leg (VBLL) reveal better performances at VBRL, keeping inside the space left inside at VBLL and right inside at VBRL. The mean of vertical deviations shows lower values at VBRL, front and back. The mean of lateral deviations has equal values to the left and to the right. Making a comparison of the Confidence Limit of Mean of the deviations, one can observe a smaller deviation at VBRL. Therefore, the better performance of VBRL is justified.

The analysis of performances in technical training evaluation highlights the total score recorded at ball instep kick and long pass. This score was compared with the estimated maximum score, the weight of the mean at outside kick in 30 sec. and the total level training related to the individual maximum value achieved.

The comparison of the relations between the variables of bipedal and unipedal balance with the level of technical training in U13 football players reveals performances. Concerning the maintaining inside the space, there are better positive connections at VBB and VBRL, while the negative connections (better effect) are present at both VBB and VBLL. Even if these connections are statistically insignificant, the sense of the relations (positive or negative) determines the influence of the variables on their performance.

These data can serve as recommendations in future studies intended to develop and implement an experimental program. The purpose of this program is the improvement of balance and technical training as well.

## Acknowledgement

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## Conflict of interest

There are no conflicts of interest to declare.

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