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**CONTENTS**

<b>Fahri Safa Çınarlı, Sena Çınarlı, Emin Kafkas.</b> Comparison of thigh muscle activations in single leg exercises: bench squat, step-up, airborne lunge .....	342
<b>Sercin Kosova, Merve Koca Kosova.</b> The effect of score types on total score in trampoline gymnastics: Example of the European Championship in Sochi 2021 .....	349
<b>Jessica Phan Zhi Xin, Rajkumar Krishnan Vasanthi, Vinoshkumar Purushothaman, Ali Md. Nadzalan.</b> Ankle range of motion and dynamic balance in recreational Sepak Takraw players with and without ankle injury - a comparative study .....	355
<b>Candra Kurniawan, Hari Setijono, Taufiq Hidayah, Hadi Hadi, Sugiharto Sugiharto.</b> The effect plyometric training with active-passive recovery for 8 weeks on performance physical abilities male judo athletes .....	361
<b>Aysegul Yapici-Oksuzoglu, Halit Egesoy</b> The effect of menstrual cycle on anaerobic power and jumping performance .....	367
<b>Alejandro Almonacid-Fierro, Jessica Mondaca Urrutia, Sergio Sepúlveda-Vallejos, Karla Valdebenito.</b> Social representations of physical education teachers concerning the game: a qualitative study in Chile .....	373
<b>Nikola Aksović, Iryna Skrypchenko, Bojan Bjelica, R. Ram Mohan Singh, Filip Milanović, Dejan Nikolić, Milan Zelenović.</b> The influence of motor skills on the short sprint results .....	382
<b>Irina Kriventsova, Yevgeniy Gorbachuk, Svitlana Chernihivska, Marina Jagiello, Abdelkrim Bensbaa.</b> Improving the means and methods of training of young fencers aged 9-11 years .....	388
Information .....	395

# Comparison of thigh muscle activations in single leg exercises: bench squat, step-up, airborne lunge

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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** Single leg exercises have some advantages in terms of time, practice and energy costs. However, the activation values that occur in different single leg exercises can be used for training planning. The aim of this research was to examine the thigh muscle activation values during three different single leg exercises.

**Material and Methods** Ten healthy male volunteers who were students of the faculty of sports sciences participated in the study. In the study, the EMG amplitude values of the vastus medialis (VM), vastus lateralis (VL), semitendinosus (SEM) and biceps femoris (BF) muscles were examined during Step-up, Bench Squat and Airborne Lunge exercises. At the same time, Quadriceps (VM+VL): Hamstring (SEM+BF) ratios were determined.

**Results** Significant differences were detected in all thigh muscles in the ascent and descent phases ( $p < 0.05$ ). While the greatest activation for the quadriceps group was seen in the airborne lunge, the greatest activation for the hamstring group was detected in the bench squat. A statistically significant difference was found in terms of exercise practices in the quadriceps: hamstring (Q:H) ratio ( $F(2,18)=12.282, p=.003$ ). It was seen that the most balanced exercise was bench squat (Q:H=2.55), and the most unbalanced exercise (agonist dominant) was airborne lunge (Q:H=5.51).

**Conclusions:** The findings show that the exercises examined can be selected depending on the purpose of the training. While bench squats can be preferred for more balanced co-activation the airborne lunge can be preferred for dominant knee extensors.

**Keywords:** electromyography, fitness, kinematic, phases.

## Introduction

The effects of single leg exercises on both performance and health have been examined. In a study, it was mentioned that single leg exercises have positive effects on regional arterial stiffness [1]. In another study, it was determined that these exercises abolished the impaired oxidative flow in the skeletal muscle of patients with type 2 diabetes and, at the same time, increased the vascular endothelial content [2]. It has been mentioned that single leg exercises are also applied by clinicians during the rehabilitation process and that they have an effect on improving aerobic capacity by reducing metabolic demand [3].

Single leg exercises are frequently examined in biomechanical studies in order to make more isolated analyzes in terms of the skeletal-muscular system [4]. In addition, it has been stated that single leg exercises are superior to double leg exercises in terms of energy metabolism [5]. High-intensity exercises are limited by hematological or cardiovascular factors rather than the oxygen capacity of the working muscle, due to the high oxygen demand or the heavy load it creates on the organism [5, 6]. At this point, it is noted that the amount of intense oxygenated blood required by the working muscles is more tolerable during exercises involving one leg or smaller muscle mass [7]. For this reason, it can be said that single leg exercises have the advantages of

energy cost and sustainable exercise.

It is necessary to compare different practices in order to design the right exercises for strength and conditioning training. The appropriate exercise choice is possible using the activation values determined during different exercises for the same muscle or muscle group [8, 9]. The findings obtained may be followed by exercise participants for their current training situations or targeted goals. At the same time, especially for clinicians, co-activation values serve as an important feedback function in the rehabilitation process and as an injury prevention strategy [10, 11]. For these and similar purposes, comparison of exercises can help in choosing the right exercise.

It is known that sagittal plane exercises are given priority in the exercise programming process [12]. It can be said that the axis in which the walking pattern is exhibited and for which the least foreignness can be felt by the organism is stepping. For this reason, stepping movements in the sagittal plane are practiced by many exercise participants. In this context, the aim of the research was to examine the thigh muscle activations during different single leg exercises in the sagittal plane. In the research, bench squat, step-up and airborne lunge movements with different difficulty levels but mainly including ascending and descending phases were examined. The hypothesis determined that the thigh muscle activity values differ in terms of exercises.

## Material and Methods

### Participants

Ten healthy male volunteers (age:  $26.7 \pm 3.65$  years; body weight:  $77 \pm 11.4$  kg; height:  $168.2 \pm 27.86$  cm) who were students of the faculty of sports sciences participated in the study. The study was approved by the Ethics Committee of Inonu University (Approval Number: 2021-2166), and conformed to the Helsinki Declaration. Written informed consent was obtained from all participants. Inclusion criteria in the study were determined as not having any musculoskeletal disorders, having at least 3 years of bodybuilding and fitness experience, and having experienced the movements before the research. Exclusion criteria were determined as experiencing any health problems, kinematic errors during the display of movement, and incorrect data measurement in activation values.

### Research Design

#### Exercise Procedure

In the research, bench squat, step-up and airborne lunge exercises were examined and the movements were analyzed as ascending and descending phases. The participants were randomized to the exercises using a computer-generated randomization list. The movements were repeated three times, and the most correct posture was analyzed after the video review (Figure 1). Although different movement patterns were examined, a goniometer was used to standardize the flexion and extension angles of the knee. The knee flexion angle was maintained at 90 degrees at the starting point of the movement, and the knee was in full extension at the end of the ascending phase of the movement. Exercises were applied at the pace that the participants chose, so that the flow of the exercises was not disturbed.

#### Electromyography (EMG) Procedure

Electrode placements followed SENIAM recommendations and were applied to the dominant leg [13]. Before the electrodes were positioned over each muscle, the skin was prepared by shaving, abrading, and cleaning with isopropyl alcohol wipes to reduce skin impedance values. Following the skin preparations, circular bipolar Ag-AgCl surface electrodes (Noraxon Dual Electrodes, Noraxon USA, Scottsdale, Arizona, USA) (diameter=1 cm and interelectrode distance=2 cm) were placed on the volunteer's right side [14]. Vastus medialis (VM), vastus lateralis (VL), biceps femoris (BF) and semitendinosus (SEM) muscles of participants were examined. In addition, Quadriceps (VM+VL):Hamstring (BF+SEM) ratio (Q:H) was determined.

#### EMG Signal Processing

Raw sEMG signals were collected using an 8-channel wireless telemetry system (Noraxon Desktop DTS, Scottsdale, AZ, USA) and were analyzed using MyoMuscle MR 3.10 Clinical Applications software (Noraxon Telemetry, Scottsdale, AZ, USA). All raw sEMG signals were first 20-500 Hz Butterworth bandpass filtered, and then root-mean square (RMS) filtered with a 100 ms time-window for movement artifact rejection and signal smoothing. RMS-filtered mean EMG signal of

exercises was expressed as microvolt ( $\mu V$ ).

#### Statistical Analysis

Findings were analyzed using GraphPad Prism 7.0 software (GraphPad Software Inc, San Diego, California, USA). The statistical analysis was initially performed by the Shapiro Wilks normality test. Repeated measures ANOVA was used to determine exercise differences. If there was a difference between exercises, Bonferroni multiple comparison test was performed to find favorite exercise type. Significance level in the study was determined as  $p < 0.05$ . Results were presented graphically, including mean and standard deviations.

## Results

The findings obtained in the research were shown as ascent phase, descent phase and Q:H ratio. A significant difference was found in all thigh muscles in the ascent and descent phases (Table 1 and Table 2, respectively).

Figure 2 shows that the exercises differ significantly in terms of muscles in the ascending phase ( $p < 0.05$ ). In the ascending phase, the highest activation for the VM and VL muscles was observed in the airborne lunge, while the highest activation for the SEM and BF was detected in the bench squat movement (Figure 2).

Figure 3 shows that the exercises differ significantly in terms of muscles in the descending phase ( $p < 0.05$ ). In the descending phase, the highest activation for the VM and VL muscles was observed in the airborne lunge, while the highest activation for the SEM and BF was detected in the bench squat movement (Figure 3).

When the activation values throughout the exercise were examined (Table 3), it was found that the Q:H ratio differed statistically significant ( $F(2,18)=12.282$ ,  $p=.003$ ). Bench squat, step-up and airborne lunge were found to be the most balanced exercises for the Q:H ratio, respectively (Figure 4). There was a statistically significant difference between bench squat and step-up and between bench squat and airborne lunge in terms of co-activation ( $p < 0.01$ ).

## Discussion

In the study, thigh muscle activation values that occur during three different exercises were examined. Significant differences were detected in terms of thigh muscles in the ascending and descending phases of the exercises ( $p < 0.05$ ). For the quadriceps group, the greatest activation was seen in the airborne lunge, while the greatest activation for the hamstring group was seen in the bench squat exercise. The most balanced exercise with the Q:H ratio was the bench squat (Q:H=2.55), while the most agonist dominant exercise was the airborne lunge (Q:H=5.51).

In clinical studies, it has been mentioned that unilateral exercises have some advantages over bilateral exercises. Especially in acute studies, time and cost are shown in terms of increasing the statistical reliability of the research [15]. Unilateral exercises are preferred in order to optimize the energy cost and minimize the catabolic effect of the exercise [5]. It can be said that single leg or one leg exercises are advantageous in terms of metabolic

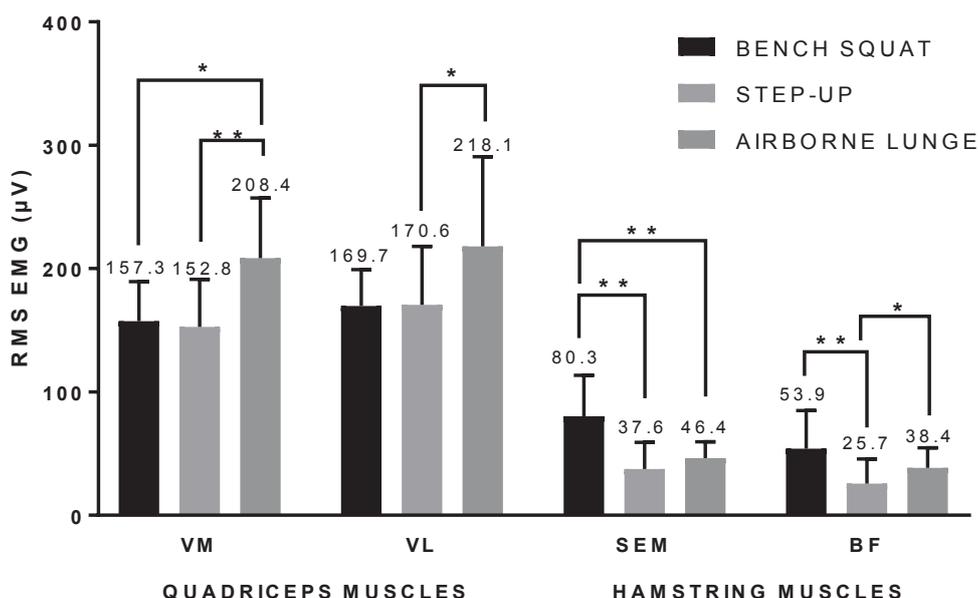


**Figure 1.** The beginning, middle and ending phases of exercises A) Bench Squat; B) Step-up; C) Airborne Lunge

**Table 1.** The mean RMS ( $\mu\text{V}$ ) values in the ascending phase during exercises

Muscles	Exercises	Mean	SD	F <sub>(2,18)</sub>	P
VM	Bench squat	157.3	32.13	14.617	<0.01**
	Step-up	152.8	38.38		
	Airborne lunge	208.4	48.85		
VL	Bench squat	169.7	29.51	4.378	.028*
	Step-up	170.6	47.48		
	Airborne lunge	218.1	72.57		
SEM	Bench squat	80.3	33.26	23.182	<0.01**
	Step-up	37.6	21.42		
	Airborne lunge	46.4	13.24		
BF	Bench squat	53.9	30.99	15.555	<0.01**
	Step-up	25.7	19.91		
	Airborne lunge	38.4	16.20		

(\*p<0.05; \*\*p<0.01; VM: Vastus medialis; VL: Vastus lateralis; SEM: Semitendinosus; BF: Biceps femoris)



**Figure 2.** Multiple comparison of the RMS values in ascending phase (\*:p<0.05; \*\*:p<0.01): (VM: Vastus medialis; VL: Vastus lateralis; SEM: Semitendinosus; BF: Biceps femoris)

**Table 2.** The mean RMS (µV) values in the descending phase during exercises

Muscles	Exercises	Mean	SD	F <sub>(2,18)</sub>	P
VM	Bench squat	122.2	29.76	8.785	.013*
	Step-up	98.4	32.03		
	Airborne lunge	141	47.53		
VL	Bench squat	128	29.33	10.700	.001**
	Step-up	106.7	34.36		
	Airborne lunge	147.4	46.58		
SEM	Bench squat	92.2	49.92	5.812	.011*
	Step-up	51.9	53.81		
	Airborne lunge	32.3	15.16		
BF	Bench squat	47.1	26.84	15.396	.002**
	Step-up	14.7	12.80		
	Airborne lunge	24.2	11.50		

(\*p<0.05; \*\*p<0.01; VM: Vastus medialis; VL: Vastus lateralis; SEM: Semitendinosus; BF: Biceps femoris)

**Table 3.** Q:H ratio of mean RMS values for the entire movement

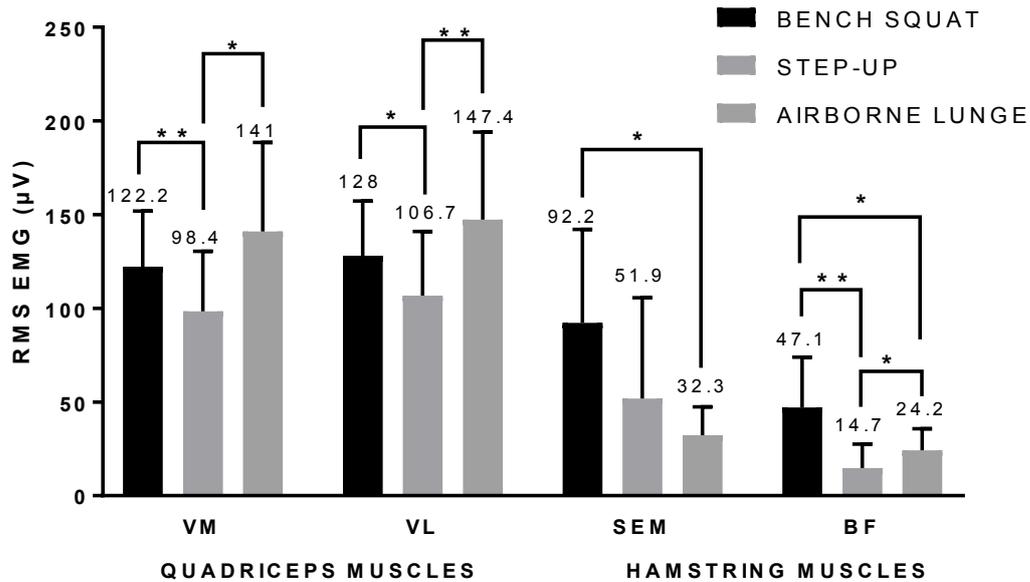
Exercise	VM+VL/SEM+BF	SD	F <sub>(2,18)</sub>	P
Bench squat	2.55	.94	12.282	.003**
Step-up	4.84	1.84		
Airborne lunge	5.51	2.31		

(\*\*p<0.01; VM: Vastus medialis; VL: Vastus lateralis; SEM: Semitendinosus; BF: Biceps femoris)

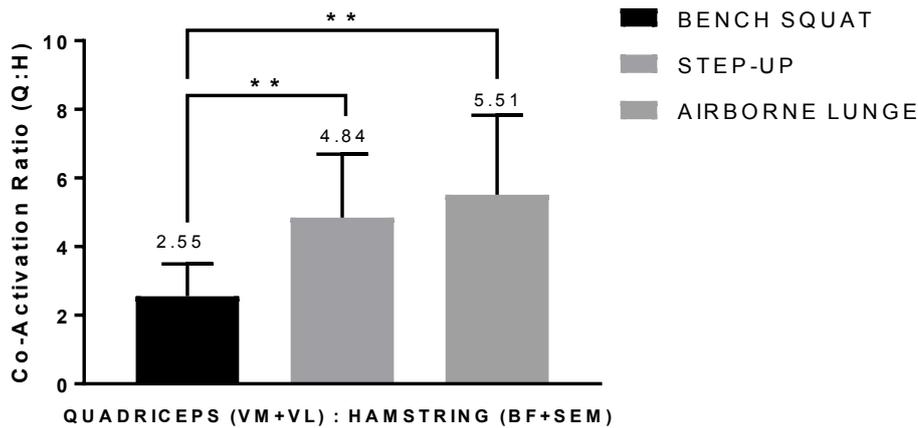
efficiency, time and cost. However, the detection of cross-chain power transfer or the inability to detect dominant-non-dominant limb differences can be expressed as limitations for unilateral exercises.

In the study, the quadriceps group showed greater EMG amplitude in the airborne lunge exercise and the

hamstring group showed this in the bench squat exercise. The findings may be due to the different difficulty levels of the exercises, as it has been mentioned that there is a relationship between Surface EMG values and motor unit activation, and EMG amplitude depends on the number of motor unit activations, size and firing rate



**Figure 3.** Multiple comparison of the RMS values in descending phase (\*:p<0.05; \*\*:p<0.01): (VM: Vastus medialis; VL: Vastus lateralis; SEM: Semitendinosus; BF: Biceps femoris)



**Figure 4.** Q:H ratio of the entire exercise (\*\*p<0.01): (VM: Vastus medialis; VL: Vastus lateralis; SEM: Semitendinosus; BF: Biceps femoris)

[16]. It has been stated that the increased value in the amplitude is an interpretable parameter in terms of the motor unit participation rate [17]. Furthermore, it has been determined that quadriceps and hamstring muscles produce higher EMG activity during high resistance in low and high resistance training practices [18]. As the need for muscle strength increases, compensation is provided to maintain the movement and increases in signal values can be seen. Therefore, the quantitative activation values seen during the comparison of different exercises can be an important parameter in determining the exercise goal. Biomechanically, the airborne lunge includes the movement between kneeling and standing. Since the body's center of gravity is closer to the ground during this exercise, the process of standing up can be more challenging for the agonist muscle, the movement between sitting and standing in the bench squat movement.

During this movement, the contact of the gluteus maximus with the bench in the starting position may have differentiated the standing up process compared to the other two exercises. When getting up from the sitting position, the hamstring muscle group in the antagonist role may have been more active for balancing. Depending on the level of difficulty, it can be stated that the exercises require different levels of motor unit participation.

In terms of the thigh muscle group, the Q:H ratio may affect exercise preference [19]. Greater hamstring activation, especially in the clinical rehabilitation phase, is a protective response to limit anterior tibial translation of the knee after injury and increase joint stability [20, 21]. It has been stated that single leg exercises can reduce the risk of tensile stress on the ACL when performed at a 30–90 degree knee flexion angle [10]. In the research, it was determined that the most balanced Q:H ratio was in

the bench squat movement and the most unbalanced ratio was in the airborne lunge movement.

### Conclusions

The activation values obtained from the exercises examined can be selected according to the purpose of the exercise to be planned. While airborne lunge can be preferred especially in quadriceps dominant exercises,

bench squat can be applied in terms of the hamstring group. Finally, when the Q:H ratio is important, it can be said that the bench squat movement can be safer, especially in terms of the balanced co-activation value demanded during the rehabilitation process.

### Conflict of interest

The authors declare no conflict of interest.

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# The effect of score types on total score in trampoline gymnastics: Example of the European Championship in Sochi 2021

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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** Trampoline gymnastics has a versatile scoring system that has evolved and become more complex over the years. This study aimed to find the effect of the difficulty (D), execution (E), time of flight (TOF), and horizontal displacement (HD) scores on the total score in male and female trampoline gymnasts.

**Material and Methods** The results of the first round in the qualification round in the individual senior category of the 27th European Championships in Trampoline Gymnastics were used for evaluation. Multiple regression analysis (the enter method) was performed to build a model between the total score and D, E, TOF, and HD scores.

**Results** According to multiple regression analyses, respectively E, TOF, D, and HD scores were predictors of the total score in the men's first routine, and D, E, TOF, and HD in the men's second routine ( $p < 0.05$ ). Although women have the same ranking as the men of the second routines, respectively E, D, TOF, and HD scores were predictors of the first routine ( $p < 0.05$ ).

**Conclusions:** The results show that the E score is critical for the first routines and the D score is critical for the second routines. The fact that the first and second routines were constructed with different strategies as per the competition rules may have caused this result. By reminding coaches and athletes of the fact that the types of scores can affect each other, it can be suggested that they adjust their target scores according to the type of routine and the stage and type of competition.

**Keywords:** trampoline, difficulty, execution, time of flight, horizontal displacement

## Introduction

The first appearance of the trampoline was in 1934 with the initiative of George Nissen, an American gymnast. It drew attention in a short time and was used for pilot air sense training in World War II. After development processes over the years, the trampoline became a Federation Internationale De Gymnastique (FIG) discipline in 1999 [1]. Gymnasts perform turns in different axes [2] high above the trampoline bed in combination with a high jump. Trampoline gymnastics, which was included in the Olympic program in Sydney 2000 [3], continues its development and is performed by more countries at a high level.

In trampoline gymnastics, routines with 10 different elements should be practiced without any interruptions. Many technical details such as not being able to land on the trampoline with both legs at the same time or touching any area other than the trampoline bed are considered interruptions by the judges. According to the results of the qualifying round routines, eight gymnasts qualify for the finals. In the senior category, the difficulty value of the four elements in the first routines in the qualifying round is added to the total score of the routine. The difficulty value of all 10 elements in the second routines in the qualifying round is included in the total score and gymnasts should not repeat the same elements in the second routine that have the difficulty value in the first routine [4]. Therefore, the gymnasts create their first and second routines with

different strategies by considering these rules.

In addition to the difficulty (D) score, there are execution (E), time of flight (TOF), and horizontal displacement (HD) scores in trampoline gymnastics evaluations. Penalty points may be deducted by the chair of judges panel. The E score is very versatile and can be subjective [5]. It is based entirely on errors that can be perceived by the human eye, and therefore it is the type of score to which the highest number of judges contribute. The basic logic of the E score is to perform movements with minimum errors in the most perfect way. Examples of such errors are showing poor body position, bent knees, and not opening in the landing phase of the element. Judges make deductions based on the rules, and the E score is calculated using two median marks.

The TOF score was included in the evaluation to increase the objective scoring [6] because it is determined by a standard electronic device. The TOF calculation starts with the gymnast's first element. As the gymnasts jump higher, the time they stay in the air will increase, thus increasing their TOF score. The HD score is a type of score that encourages the gymnast to step on the midpoint of the trampoline during the routine. Points are deducted or not for each element landing, depending on where the feet touch from the lines, which determine the distance in the trampoline bed [7]. This score type was the last added criterion for calculating the total score in trampoline gymnastics [4].

The first European Championship in trampoline

gymnastics was held in Paris in 1969. It continues to be organized every two years (“European Gymnastics”). The last European Championship was held between April 29<sup>th</sup> and May 2<sup>nd</sup>, 2021, in Sochi, Russia. Considering that large events could not be organized for about a year due to the effects of COVID-19, this championship was an important meeting for many federations. The fact that the Olympics will be held approximately 3 months after this championship is also important in terms of evaluating the competitors. As explained above, scoring in trampoline gymnastics is performed with more than one score type. It is important to know which of these score types is more effective in different types of routines grades to guide athletes and trainers. In this study, the aforementioned evaluation was made by using the results of the European Championship, which is a high-level competition and has high participation. The aim of this study was to investigate the effect of the types of scores (D, E, TOF, HD) on the total score in male and female trampoline gymnasts.

**Materials and Methods**

*Participants.*

The numbers of senior male and female gymnasts participating in the individual competition were 46 and 32, respectively. Routines in which 10 elements could not be completed are excluded from the evaluation. Accordingly, in the men’s competition, 41 routines were evaluated in the first routine and 33 routines were evaluated in the second routine. For women, this number was 28 for the first routine and 26 for the second routine.

*Procedure.*

The data obtained in the 27<sup>th</sup> European Championships in Trampoline Gymnastics (April 29<sup>th</sup> - May 2<sup>nd</sup>, 2021, Sochi, Russia) were used in the study. The first-round results of the qualification round of individual competition of the male and female gymnasts competing in the senior category were evaluated. The first round of the qualifying round consisted of two routines. The final score is calculated by collecting four score types (E, D, TOF, HD) in all routines. However, in line with the rules, only four D-point elements are added to the total score in the first routine, whereas the D points of all 10 elements in the second routines are included in the total score. The results

of the competition were obtained from the website of SPORTTECH Ltd, the official collaborator of European Gymnastics [8].

*Statistical Analyses.*

Descriptive analyses were performed, and the results were expressed as mean and standard deviation for the variables. The normality of the variables was examined using the Shapiro-Wilk test and normal distribution was observed ( $p > 0.05$ ). The independent sample t-test was used to compare the score types of the first and second routines according to sex. The correlation between the total score and D, E, TOF, and HD scores was evaluated using Pearson’s correlation analysis. Multiple regression analysis assumptions were tested. There was a linear relationship between the independent variables and the dependent variable. Multiple linearity was appropriate [9]. VIF values were within normal limits [10]. Covariance was appropriate. ‘Mahalanobis distance’ [11], ‘Cook’s distance’ [12] and ‘centered leverage value’ were in the correct range of values. Multiple regression analysis was performed to build a model between the total and E, D, TOF, and HD scores, the enter method was used as the variable selection method. Model fitting performance was assessed using the coefficient of determination ( $R^2$ ). Regression coefficients and their 95% confidence intervals (CI) are also given. A p-value of  $< 0.05$  was used as the level of statistical significance. The IBM SPSS Statistics for Windows Ver. 20 software program (Armonk, NY: IBM Corp., 2011) was used for the statistical analyses.

**Results**

There were significant differences between male and female gymnasts in all score types except for the HD score of the first routine and E and HD score of the second routine (Table 1).

Multiple regression analysis was run to predict the men’s first routine total score from E, D, TOF, and HD. These variables statistically significantly predicted first routine total scores,  $F(4,36)=1568.52$ ,  $p < 0.001$ ,  $R^2=0.994$ . Multiple regression analysis was run to predict the men’s second routine total score from E, D, TOF, and HD. These variables statistically significantly predicted second routine total scores,  $F(4,28)=8555.44$ ,  $p < 0.001$ ,

**Table 1.** Comparisons of scores of the gymnasts’ first and second routines

Score Types	1st Routines			p	2nd Routines		
	Mean±SD		p		Mean±SD		p
	Women n=28	Men n=41			Women n=26	Men n=33	
E	16.86±1.15	17.39±1.00	<b>0.045*</b>	14.94±1.07	15.24±0.90	0.238	
D	4.20±1.05	5.58±0.55	<b>0.001**</b>	11.81±1.95	15.88±1.43	<b>0.001**</b>	
HD	9.22±0.25	9.33±0.28	0.131	9.06±0.19	9.12±0.33	0.359	
TOF	15.83±0.67	17.56±0.69	<b>0.001**</b>	15.05±0.44	16.61±0.55	<b>0.001**</b>	
TOTAL	46.10±2.06	49.86±1.85	<b>0.001**</b>	50.74±2.80	56.85±2.34	<b>0.001**</b>	

\* $p < 0.05$ , \*\* $p < 0.005$ , E: Execution score, D: Difficulty score, HD: Horizontal Displacement score, TOF: Time of Flight score, Total: Total score

$R^2=0.999$ . The results are presented in Table 2.

**First Routine Total Points:**

$$-1.105+1.017*E+0.96*D+1.085*HD+1.014*TOF$$

**Second Routine Total Points:**

$$-0.168+0.995*E+0.992*D+1.046*HD+0.996*TOF$$

Multiple regression analysis was run to predict the women's first routine total score from E, D, TOF, and HD. These variables statistically significantly predicted first routine total scores,  $F(4,23)=31475.50$ ,  $p<0.001$ ,  $R^2=0.999$ .

Multiple regression analysis was run to predict the women's second routine total score from E, D, TOF, and HD. These variables statistically significantly predicted second routine total scores,  $F(4,21)=283.23$ ,  $p<0.001$ ,  $R^2=0.978$ . The results are presented in Table 3.

**First Routine Total Points:**

$$-0.369+0.979*E+0.995*D+0.989*HD+1.053*TOF$$

**Second Routine Total Point:**

$$-2.248+1.052*E+1.116*D+1.319*HD+0.807*TOF$$

In both male and female gymnasts, the highest correlation in the first routine was between E and total score. In the second routine, the highest correlation was found between D and total score (Table 4).

**Discussion**

This study focused on defining the effects of different score types on the total score in trampoline gymnastics. There are some similar studies in the literature on artistic gymnastics, one of the other Olympic branches of gymnastics [13-16], and trampoline gymnastics [5,17]. To our knowledge, no study in the literature has investigated the effect of score types and included the HD score, which is added to the evaluation in the last cycle. Therefore, the results of this study will fill an important gap in the literature. The most important finding of the study was that the E score was the highest predictor in the first

**Table 2.** Multiple regression analyses for total score in men gymnasts

Score Types	Sta.Coefficient			95% CI	R <sup>2</sup>	ANOVA	
	$\beta$	t	p	Min-Max		F	p
E <sub>1stR</sub>	0.550	30.788	< .001	[0.950-1.083]	0.994	1568.52	<0.001
D <sub>1stR</sub>	0.289	19.464	< .001	[0.860-1.060]			
HD <sub>1stR</sub>	0.168	10.826	< .001	[0.882-1.289]			
TOF <sub>1stR</sub>	0.381	22.132	< .001	[0.921-1.107]			
Constant <sub>1stR</sub>	-1.105	-1.079	.288	[-3.183-0.973]			
E <sub>2ndR</sub>	0.384	60.869	< .001	[0.962-1.029]	0.999	8555.44	<0.001
D <sub>2ndR</sub>	0.607	91.365	< .001	[0.970-1.014]			
HD <sub>2ndR</sub>	0.146	25.854	< .001	[0.963-1.129]			
TOF <sub>2ndR</sub>	0.235	32.045	< .001	[0.933-1.060]			
Constant <sub>2ndR</sub>	-0.168	-0.340	.736	[-1.179-0.844]			

$\beta$ : Standard coefficient beta except constant, 1stR: First routine, 2ndR: Second routine, E: Execution score, D: Difficulty score, HD: Horizontal Displacement score, TOF: Time of Flight score, Total: Total score

**Table 3.** Multiple regression analyses for the total score in female gymnasts

Score Types	Sta.Coefficient			95% CI	R <sup>2</sup>	ANOVA	
	$\beta$	t	p	Min-Max		F	p
E <sub>1stR</sub>	0.546	134.104	<0.001	[0.964-0.994]	0.999	31475.50	<0.001
D <sub>1stR</sub>	0.510	164.647	<0.001	[0.983-1.008]			
HD <sub>1stR</sub>	0.120	39.359	<0.001	[0.937-1.041]			
TOF <sub>1stR</sub>	0.341	84.534	<0.001	[1.027-1.078]			
Constant <sub>1stR</sub>	-0.369	-1.276	0.215	[-0.968-0.230]			
E <sub>2ndR</sub>	0.402	12.286	<0.001	[0.874-1.231]	0.978	283.23	<0.001
D <sub>2ndR</sub>	0.775	16.041	<0.001	[0.971-1.260]			
HD <sub>2ndR</sub>	0.088	2.148	0.044	[0.042-2.596]			
TOF <sub>2ndR</sub>	0.125	3.264	0.004	[0.293-1.320]			
Constant <sub>2ndR</sub>	-2.248	-0.365	0.719	[-15.053-10.557]			

$\beta$ : Standard coefficient beta except constant, 1stR: First routine, 2ndR: Second routine, E: Execution score, D: Difficulty score, HD: Horizontal Displacement score, TOF: Time of Flight score, Total: Total score

**Table 4.** The correlations between total score and other score types

Sex	Routines	n	Mean±SD					
			TOTAL	r	E	D	HD	TOF
Women	First	28	TOTAL	r	0.861**	0.575**	-0.153	0.749**
	Second	26			0.617**	0.878**	-0.394*	0.701**
Men	First	41	TOTAL	r	0.874**	0.477**	0.369*	0.823**
	Second	33			0.664**	0.837**	0.346*	0.788**

\*\*p<0.01, \*p<0.05

routines for both men and women, and the D score was the highest predictor in the second routines.

In the men’s first routine, respectively TOF, D, and HD scores were effective for determining the total score after the E score. These results are not surprising. Counting the difficulty value of only four elements in the first routines caused an increase in the importance of E and TOF scores. In terms of homogeneity [17], D scores in the first routines may be more homogeneously distributed compared with other score types. Leskošek, Čuk and Peixoto [5] found the same importance of ranking (E, TOF, D) in men’s routines at the European Championship in 2014. However, unlike the current study, the same ranking was valid in both the first and second routines. In this study, respectively D, E, TOF, and HD scores were predictors of second-routine total scores. Gymnasts put the highest difficulty elements that they can do in their routines because the difficulty values of all 10 elements in the second routines are included in the scoring. This situation is related to the technical skills and risk-taking preferences of the athletes. It is expected that the predicting factor of the D score will increase here. It can be said that the effect of the D scores increased in this study compared with the studies in the literature based on the former evaluation formats and Code of Points [5,17]. This can be attributed to the increasing differences between gymnasts’ D scores with technical developments and increasing contention over the years. The importance of TOF scores in men’s first routines should also be emphasized. The results of the study indicate that men have higher averages in TOF scores than women. This situation allowed TOF scores to have important effect on men’s first routine. Gymnasts who can jump higher will use it as a score directly and will have more time in the air to practice elements, which can help increase other score types [18].

Although the prediction order of women’s second routine is the same as in the men’s, there is a difference in the first routine. The D score seems more effective than the TOF score. Despite the D counting of limited elements in the first routines, it was surprising to find this result. Tactical approaches such as at which stage of the routine the D score elements will be performed, or rules such as the elements which D score is counted in the first routine, cannot be repeated in the second routine, are taken into

account in the creation of the routines. Due to all these reasons and technical qualifications, the first routine D scores of female gymnasts may differ and this may lead to an increase in the decisiveness of D scores.

Especially in the first routines, the importance of the E score is apparent. Although the evaluation is quite different, it has been shown that the E score is more decisive in another branch of gymnastics [19]. Keeping the E score high requires a simple logic for the athlete to perform the movements that they can easily do, which can lead to lower D scores, and increase the jump height, thus the TOF score will also increase. While trying to keep the E score high for trainers and athletes, not being able to increase the D score can be one of the greatest contradictions. This contradiction is also seen in other gymnastics branches [20]. Moreover, while increasing the D score, the risk of falling or not being able to continue the routine may increase. In general, coaches and athletes can be advised to adjust their risk-taking situations according to the stage of the competition (i.e. first round of the qualifying round, second round of the qualifying round, final) while making this decision. Also, the presence or absence of opponent athletes in the competition may be reviewed when making this decision [21].

Although it is a well-known and observed situation in competitions that men have higher TOF and D scores, the E score was also found high in the first routine in this competition. In particular, female gymnasts can be recommended to develop their training programs to improve their E scores, which can be achieved by not including elements in their routines that they have not yet repeated sufficiently to perform them perfectly. The HD score remained the 4th effect by ranking for all sexes and routine types. In this score type, which is obtained by deducting mistakes out of 10 points, the fact that the gymnasts achieved close scores in this competition may have caused this result. In the literature, it has been shown that gymnasts may have lower TOF and HD scores in the second routines than in the first routines. In this context, it is important to find an optimal D score that will not negatively affect the total score [22].

**Conclusions**

As a result, because the routine design is made with different strategies in the qualifying round in trampoline

gymnastics, the order of predicted total scores of the score types in the first and second routines is different. In this study, it was shown that the E score in the first routines and the D score in the second routines were prioritized for both men and women. All coaches and athletes can be advised to consider these findings while designing routines. Also, because all score types can be interconnected and affect each other, as discussed in the text, it seems important to

determine optimal target scores for different routine types and competition types.

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#### Conflicts of interest

There is no conflict of interest.

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# Ankle range of motion and dynamic balance in recreational Sepak Takraw players with and without ankle injury - a comparative study

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## Abstract

**Background and Study Aim** Sepak Takraw (ST) is considered Malaysia's national sport, and the nature of this sport requires players to be sufficiently acrobatic. Therefore, players were expected to jump and regain their balance, challenging their dynamic balance (DB). Nonetheless, range of motion (ROM) is closely related to balance. Hence, this study aimed to compare recreational ST players' ankle ROM and DB differences with and without ankle injuries.

**Material and Methods** The cross-sectional study in which 30 participants were assigned purposively according to players with an ankle injury (n=15) and without ankle injury (n=15) based on the position statement of the International Ankle Consortium (IAC). One time ankle Range of Motion and Dynamic balance was measured using a universal goniometer and Star Excursion Balance Test (SEBT), respectively, for both groups.

**Results** Independent T-test was performed to identify the significant differences ( $p < 0.05$ ) of SEBT and ROM between the non-injured leg and injured leg within the injured group to the non-injured group. Ankle eversion and dorsiflexion between the injured and non-injured groups did not show any significant difference with  $p = 0.35$  &  $p = 0.53$ , respectively. As for SEBT, only posteromedial and medial of the injured leg did not show a significant difference  $p > 0.05$ . All other ankles ROM and the SEBT score demonstrated a statistically significant difference  $p < 0.05$ .

**Conclusions:** ROM and DB training/rehabilitation should be incorporated to all the injured group ST sports players regardless of which leg is affected to optimize ankle function and the game performance.

**Keywords:** athletics injuries, team sports, sports, range of motion, postural balance

## Introduction

Sepak Takraw (ST) is considered Malaysia's national sport, and it has the combination of few elements from other sports such as soccer, volleyball, baseball, badminton, and the ancient sport of Sepak Raga [1]. It is a sport widely known in South-East Asia and has transpired to other countries worldwide [2]. Sepak Takraw is a game where the ability to kick and juggle the ball around with the acrobatic moves of gymnasts is required. Lower extremities are used instead of upper extremities, and as in a volleyball, there are passes, sets and spikes in play. However, players can utilize their head, chest, feet and thighs to propel the ball over the net. Whether a player is a server, spiker, nor feeder, they ought to have good aerial agility with precision, leg strength, timing and skills [3].

Players are expected to jump and regain their balance, which is a challenge to their dynamic balance (DB) [2]. Nonetheless, range of motion (ROM) is closely related to balance that stretching could improve dynamic balance in athletics. There is only one known study done for Sepak Takraw, which was conducted in Japan to investigate injuries sustained with physical characteristics. In a study by Kubo et al [4] the ankle strain as the second-highest injury sustained, whereas the hamstring strain injury was the highest. Sprains are the recurrent injuries in high-risk sports, up to 80%.

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Aside from sportspeople, an initial ankle sprain affects around 8% of the population. Those with a history of sprains suffer from residual or chronic discomfort, recurrent sprains, and perceived instability [5]. In the ankle joint, ankle sprain is the most recurrent injury that occurred which 20% of it will develop into chronic ankle instability (CAI) [6]. Thus, CAI became the interest of this research in defining 'Injured' ST players.

A study [7] mentioned that specific ROM where dorsiflexion influences the DB in individuals with CAI, which subsequently established difficulty in performing a portion of the Star Excursion Balance Test (SEBT). However, the authors stated that measures of ROM at other joints were not obtained, which confirms the need to further study it in other joint ROM of the ankle besides dorsiflexion, which are eversion, inversion, and plantarflexion. Looking deeper, a decrease in ankle ROM declines the balance control function on the ankle strategies [8]. However, there is a decline in DB and ROM through observation of dorsiflexion in individuals with CAI [9].

The investigation was done in integrating these data into this sport; ST players can benefit from revising a training regimen, rehabilitation programs for those who have CAI problems, and reducing or avoiding the incidence of recurrence of an ankle injury. Hence, this study compares ankle ROM and DB in recreational Sepak Takraw players with and without ankle injury (CAI).

**Materials and Methods**

*Participants*

In this cross-sectional study, participants (n=30) with a mean age of 24 ±4.03 in non-injured group and 24.9±3.81 from injured group were recruited and informed about the study and obtained written consent. The faculty Ethical Committee of the institution has (FHLS/RAC/JUL/6) approved this study.

Based on the International Ankle Consortium (IAC) where the injured group should have at least have one significant history of ankle sprain as follows: “the initial sprain must happen at least 12 months before, have inflammatory symptoms (pain, swelling, etc.), at least one interrupted day of desired physical activity, the latest injury must happen more than three months before study enrolment and history of the previously injured ankle joint “giving way” and recurrent sprain and “feelings of instability where the participants ought to have at least two reports of giving way in the six months before study enrolment”. Participants with a history of previous surgeries, fractures in either limb of the lower extremity, musculoskeletal injuries of the lower extremity in the past three months, which impacted joint integrity and function (i.e., sprains, fractures) that caused at least one interrupted day of desired physical activity and had bilateral CAI was excluded.

In our study, the participants from the non-injured group were excluded if they had a history of ankle sprain, fractures and past surgeries in both the lower extremity and acute musculoskeletal injuries of other joints in both the lower extremity in the past three months.

*Procedure*

The independent variables used in this study are the subjects, with or without any injuries (CAI), and the dependent variables are the ankle ROM and DB. Once the participants were concerned to participate in the study, they were categorized into the ‘injured’ group, which was further divided into ‘injured leg’ and ‘non-injured leg’ and non-injured group before quantitative measurement of ROM and SEBT.

*Ankle Range of Motion (ROM)*

Participants were put into a long sitting position, knee slightly flexed to 20° [10] and ankle in a neutral position on the ground. The universal goniometer was the tool used to measure ankle ROM, and the lateral malleolus was the fulcrum, whereas the stationary arm was parallel to the fibula and tibia. The moving arm follows the 5th metatarsal. The starting position for the ankle is in a neutral position. Participants were asked to plantarflex and dorsiflex the ankle without moving the toes to control the toes contribution. Participants must return to the initial position before taking another reading. Three readings are taken each, and the average records were utilized [11].

Participants were asked to sit on high sitting to measure eversion and inversion. Between both malleoli, the anterior part of the ankle was the fulcrum; the stationary arm was parallel to the tibia and the moving arm follows the 2nd metatarsal. Similar, the starting position for the ankle is in a neutral position. However, this time, the toe contribution

is not controlled. The initial position was returned, and the second measurement is taken. Recordings of three readings taken and then averaged out [12]. The data for both left and right ankle ROM were retrieved.

*Dynamic Balance – Star Excursion Balance Test (SEBT)*

SEBT was used to measure the dynamic balance of the participants. With hands-on the hip, participant’s squat with one leg and the non-stance limb lightly touches one point along with all eight directions without shifting weight or rest on the ground at any given time during the test. The 8 points of direction – anterior, anteromedial, anterolateral, medial, lateral, posterior, posteromedial, and posterolateral challenge the DB of participants. Participants are not allowed to return to the center point during the test. The furthest point that participants could reach were marked and measured using a measuring tape. Participants that failed to follow these stipulations were disqualified. Five minutes of warm-up in their intensity level and four practice attempts were allowed before the actual recordings. Three records will be taken with 5 seconds of rest between each reach were given [7]. The data for both left and right stance retrieved.

*Statistical Analysis:*

Quantitative data of SEBT and ankle ROM of each player was measured and analyzed using SPSS version 23. Descriptive statistics are portrayed as mean ± standard deviation. Since it is normal distribution data, we used an independent t-test to compare the differences of SEBT and ROM within the non-injured and injured leg of the injured group and between the injured and non-injured group. A p-value of <0.05 was considered statistically significant in this study.

**Results**

Twenty recreational Sepak Takraw male players volunteered to participate in this research. Among the fifteen participants under the injured group, eleven of the players had CAI on their right leg whereas four had it on their left leg (Table 1).

**Table 1.** Demographics of the participants

<b>Groups</b>	<b>Non-Injured group</b>	<b>Injured group</b>
Participants	n=15	n=15
Age (mean ± SD)	24±4.03	24.9±3.81
Height (cm) (mean ± SD)	173.1±6.40	169.4±5.27

SD-Standard Deviation

In Table 2, injured group had an increase in the dorsiflexion, plantarflexion and inversion except for eversion had a decrease ROM comparing to the Non-injured group.

Comparing the Injured leg within the injured group to the non-injured group exhibit no significant difference (p>0.05) in dorsiflexion and eversion (Table 3). This outcome also surfaced similar result while comparing the

**Table 2.** Comparison of ROM degree (Mean±SD) within Injured group (Injured leg & non-injured leg) with Non-injured group

Motions	Dorsiflexion	Plantarflexion	Inversion	Eversion
Injured Group Injured leg	28.6±4.51*	33.13±8.62*	32.4±5.11*	9.9±3.55*
Injured Group Non-injured leg	29.3±4.37*	29.47±7.9*	32.93±6.11*	10.17±5.03*
Non-injured Group	24.15±5.56*	22.33±2.77*	22.72±4.06*	11.4±3.55*

\*Mean±SD of ROM in degrees, SD-Standard Deviation

**Table 3.** Significance level of ROM within Injured group (injured leg & non-injured leg) with Non-injured group

Motions	Dorsiflexion	Plantarflexion	Inversion	Eversion
Injured leg vs Non-injured group	0.066 <sup>†</sup>	0.003*	0.000*	0.357 <sup>†</sup>
Non-injured leg vs Non-injured group	0.034*	0.021*	0.000*	0.535 <sup>†</sup>

\*p<0.05, <sup>†</sup>p>0.05

**Table 4.** Comparison of SEBT (Mean±SD) within Injured group (Injured leg & non-injured leg) with Non-injured group.

Directions	Ant	Ant.L	Lat	Post.L	Post	Post.M	Med	Ant.M
Injured Group Injured leg	84.87±8.22*	76.4±13.39*	73.67±6.91*	72.63±9.99*	70.27±9.3*	68.33±10.21*	69.4±12.1*	66.97±11.42*
Injured Group Non-injured leg	85±8.1*	76.93±15.57*	73.77±4.4*	75±9.2*	69.6±9.06*	64.97±10.7*	63.9±7.35*	66.9±11.63*
Non-injured Group	93.77±3.9*	93.55±4.88*	90.05±5.19*	83.6±5.29*	79.63±5.62*	73.17±3.43*	77.12±3.71*	84.28±2.86*

\*Mean±SD of SEBT in centimeters, SD-Standard Deviation, Ant-Anterior, Ant.L-Anteriolateral, Lat-Lateral, Post.L -Posteriolateral, Post-Posterior, Med-Medial, Ant.M-Ateriomedial. (Mean±SD).

**Table 5.** Significance level of SEBT within Injured group (injured leg & non-injured leg) with Non-injured group.

Directions	Ant	Ant.L	Lat	Post.L	Post	Post.M	Med	Ant.M
Injured leg vs Non-injured group	0.009*	0.003*	0.000*	0.009*	0.016*	0.184 <sup>†</sup>	0.081 <sup>†</sup>	0.001*
Non-injured leg vs Non-injured group	0.009*	0.008*	0.000*	0.022*	0.009*	0.042*	0.000*	0.001*

\*p<0.05, <sup>†</sup>p>0.05 Ant-Anterior, Ant.L-Anteriolateral, Lat-Lateral, Post.L -Posteriolateral, Post-Posterior, Med-Medial, Ant.M-Ateriomedial.

eversion ROM of non-injured leg within the injured group to the non-injured group (Table 3).

In table 4, the non-injured group were able to reach further than the injured group in SEB test. Posteromedial plane and Medial plane SEBT gave a result of no significant difference (Table 5).

### Discussion

Our study indicates that there were significant differences in the mean±SD of ankle ROM in all planes. Excessive ROM was observed in ankle dorsiflexion, plantarflexion and inversion in the injured leg compared to the non-injured group, and this is suggestive of ankle hypermobility in the injured group. Nevertheless, profoundly reduced the amount of ankle eversion ROM compared to the other movements in the injured leg. In contrast, the previous study results observed a decrease in the dorsiflexion range in the CAI population [13-15]. The

current study found that there is gross hypermobility in ROM in all planes in the injured leg. The inversion joint laxity, anterior joint laxity, increased tibiotalar anterior translation and subtalar hypermobility following CAI was the potential cause for this hypermobility [16, 17]. Interestingly, the present study detected a more significant difference in inversion ROM in both the injured and non-injured groups. This report coincides with the statement made in the earlier study that a more substantial amount of inversion and plantar flexion of the foot to tibia was noted in the CAI population compared to healthy subjects [18, 19].

Furthermore, the result of this study provides a fascinating report that the ROM in the non-injured leg and non-injured group also has dramatic significance except for eversion. The possible rationale for these findings aligns with the former study that people with CAI would have poor postural, neuromuscular control and compromised

proprioception. Additional literature also attests that CAI affects both the injured and uninjured ankles due to the disrupted sensorimotor system [20, 21]. Earlier investigations affirm no significant difference between ankle dorsiflexion in subjects with CAI compared to the control or control group [22]. This exposition concurs with the current study regarding dorsiflexion ROM between the injured leg and the non-injured group. The disparity findings in this study regarding ankle dorsiflexion ROM in the non-injured leg within the injured group raise a recommendation for further research to comprehend the reason behind this phenomenon. Additionally, this research also bestows no effect on ankle eversion range regardless of CAI or otherwise. On the other hand, ankle plantarflexion and ankle inversion showed significant differences; thus, rehabilitation should focus on these two planes regardless of the injured leg.

The current study found that the dynamic balance in posterior, posterior medial and medial excursion of the injured leg shows lesser reading than the non-injured leg in the injury group. However, this study result differed from the previous investigation in which identified excursion deficit was only in the posterior medial direction in subjects with CAI [15]. On the contrary, the previous study also observed that anterior reach was more affected but not the posterior medial and Posterior lateral reaches because mechanical restrictions would alter the anterior spread while the posterior medial and Posterior lateral depends on the strength and postural control in SEBT [23].

In this research, the overall non-injured group had a better dynamic balance when compared to the injured group at all distances. The extent of our study also declares that there is a significant difference in dynamic balance in all lengths except in posterior medial and medial directions between an injured leg and a non-injured group. Although there is no significance in posterior medial and medial distances, dynamic balance of the injured leg in anterior, anterolateral, lateral, posterior and posterolateral directions shows greater significance than the non-injured leg. Similar to earlier literature, where the outcome showed that the injured leg reached significantly less when compared to the non-injured leg or non-injured group [14, 24, 25]. In addition, the same pattern of findings was observed while examining the dynamic balance between football and basket players with CAI in which the SEBT shows a significant difference between injured and non-injured leg in players [26].

In our study, we also reported that posteromedial and medial plane had no significance (p-value 0.184 and 0.081 respectively) between the injured leg and non-injured group, it is contrasted with the findings from the former study that injured leg had a significant difference in all the planes of SEBT in CAI subjects [25]. Subsequently, another investigation demonstrated that the bilateral impairment of proprioception accompanies unilateral ankle instability is evident [27]. This result also corroborates our findings, in which there is a substantial significance in dynamic balance in all planes between the non-injured leg and the non-injured group. The potential source of the symptom is from the adjustment in the central nervous system that appears as a neuromuscular deficit in the uninjured lower extremity joints [28].

In the future, research with a large population considers other contributing factors that may affect the SEBT performance, such as proprioception and muscle strength in the lower limb in Sepak Takraw players. Next, this study is limited to 18 to 30 years old, which would broaden to investigate other age groups. Irrespective of the injured or non-injured leg, the inversion and plantar flexion ROM is more significant between the injured and non-injured groups. Hence, future studies can analyze the factors influencing the impaired ROM in the normal leg in these players to prevent further injury in the proximal joints of both lower extremities. It is established that CAI players have a considerable difference when contrast to the non-injured group in terms of ROM and DB. Thus, regardless of which leg is affected, both limbs should endorse ROM, DB or multicomponent training/rehabilitation to improve ankle function [29].

### **Conclusions**

Ankle plantarflexion and inversion exhibited significant difference in injured group versus non-injured group. However, only ankle dorsiflexion from the non-injured leg showed the same as well. SEBT revealed that all planes had significant difference in injured group versus non-injured group except for posteromedial and medial of the injured leg. ROM and DB training/rehabilitation should be done on the injured group regardless of which leg affected to optimize ankle function.

### **Conflicts of interest**

There is no conflict of interest.

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# The effect plyometric training with active-passive recovery for 8 weeks on performance physical abilities male judo athletes

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## Abstract

**Background and Study Aim** Judo is a popular sport with dynamic characteristics and requires high physical abilities to achieve achievement. The purpose of this study was to analyze the effects of plyometric exercises with active-passive recovery for eight weeks to improve the physical ability of male judo athletes.

**Material and Methods** This study used an experimental method. A total of 36 male judoka participated as samples and were randomly divided into three groups. The plyometric experimental group with active recovery (21.8±1.78 years, 1.70±0.06 m, 71.1±13.5 kg), plyometric experimental group with passive recovery (21.7±2.53 years, 1.71±0.06 m, 63.8±10.1 kg), and the control group (21.4±2.30 years, 1.72±0.05 m, 67.4±7.76 kg). The training program was conducted for eight weeks with a frequency of 3 times/week. The experimental group was treated with plyometric training after warm-up, judo training, and post-exercise active-passive recovery intervention. The control group continued regular judo training. The statistical analysis procedure used the ANOVA test to determine the difference and comparison of the pre-test and post-test mean values in the control and experimental groups with a significance level ( $p < 0.05$ ).

**Results** The results showed differences in the average value of experimental and control groups found significant to the VO<sub>2</sub>Max endurance and leg power. Meanwhile, no significant difference occurred in left and right grip strength, flexibility, and speed.

**Conclusions:** The study concluded that plyometric training with active-passive recovery positively affects male judoka's VO<sub>2</sub>max endurance and leg power.

**Keywords:** plyometric training program, active-passive recovery, performance physical ability

## Introduction

Judo is a martial art sport that originated in Japan. Judo is one of Indonesia's most popular martial arts sports because it competed in various single-event and multi-event national championship competitions. To get the best achievement or maximum points in a judo match. A judoka must have optimal physical performance resulting from the training process [1]. Periodization of the training program is a strategic step in training process to maintain and control the condition of athletes during training, as well as maximize athlete performance during matches [2]. One component of the martial arts training program is applying appropriate stress levels to optimize adaptation (improvement) and developing various physical qualities of athletes for competition preparation [3]. Thus, the given training program must focus on the load to be given [4], and athletes achieve maximum physical ability because training aims to improve performance based on morphological and functional adaptations [5].

The characteristics of the sport of judo are dynamic and require good physical strength [6]. When practicing or competing, judo athletes need much randori, uchikomi, slamming, and ground techniques to defend and attack opponents [7, 8]. Judo sport characteristics require

strength, speed, flexibility, power, VO<sub>2</sub>Max endurance, and anaerobic also plays an essential role as an energy system to support Judoka performance [9, 10]. In addition, in judo training, there will be an increase in heart rate (HR) which causes instability in body condition. This, of course, requires a proper recovery process and is needed to accelerate the decrease in heart rate after exercise [11]. T.O. Bompa and Buzzichelli [12] explained, their ability to recovery influences about 50% of athletes' best performance.

Recovery is a process that is directly related to the training load used [13]. Trainers must understand the needs, determine effective recovery methods [14], to restore lost energy, and repair damaged muscle tissue systems after exercising [15]. The impact resulting from proper recovery after exercise will increase physical quality; an athlete needs a good recovery process to return his physical condition to its original state [16]. It is still challenging to find an appropriate recovery method that incorporates plyometric training in judo training from previous plyometric training. As stated by Yamagishi [17] that, it is essential to determine recovery methods in the form of active and passive appropriate post-exercise to facilitate maximum achievement, prevent neuromuscular disorders, and plyometric training has been shown to increase the anaerobic power output of athletes [18, 19].

This experimental study aims to analyze the effect

of plyometric training with active-passive recovery on judoka physical abilities. The involvement of judoka in the scope of study aspect distinguishes it from other studies related to plyometric training with active-passive recovery. This study also aims to provide information and input on the effective use of plyometric training with active-passive recovery to obtain top judoka physical ability performance.

**Material and Methods**

*Participants*

A total of 36 experienced male judoka participating in the provincial level training camp voluntarily participated as a sample in the study. Samples were grouped randomly and divided into three groups, including 11 judoka plyometric experimental groups with active recovery (21.8±1.78 years, 1.70±0.06 m, 71.1±13.5 kg), 11 judoka plyometric experimental groups with passive recovery (21.7±2.53 years, 1.71±0.06 m, 63.8±10.1 kg), and 11 judokas in the control group (21.4±2.30 years, 1.72±0.05 m, 67.4±7.76 kg).

*Design and Procedure*

This research is an experimental study with a quasi-experimental approach design [20]. This study was previously confirmed through ethical stage clearance on the health research ethics commission institution State University of Semarang. To avoid data bias in the study, collecting research data was carried out before and after giving treatment for eight weeks. Data collection instruments were carried out in the form of tests and measurements, including anthropometric measurements (height and weight), VO2Max endurance (multistage fitness test), hand-grip strength (hand-grip dynamometer), body flexibility (sit and reach test), speed (30-meter speed test), and leg power (force plate test) [21,22]. The following describes the procedure for the treatment protocol in the study:

*Training Protocol*

The judo training program was applied to the three groups for eight weeks (3 days/week). In each training session, the experimental group and the control group were trained for 90 minutes. After warming up for 15-20 minutes, the experimental group was given plyometric training before practicing judo in 15 variations of upper and lower plyometric movements. Meanwhile, the

control group immediately did regular judo exercises. Furthermore, after the training, the experimental group was given active and passive recovery interventions for 10-20 minutes. The active recovery method aims to restore energy and gradually reduce muscle fatigue while still activating muscle performance to accelerate blood circulation back to normal. While the passive recovery method given aims to restore energy to its original state with complete or total rest. This is to reduce the effects of muscle fatigue, reduce lactate after exercise and return to homeostasis.

*Statistical Analysis*

They were testing statistical data of this study using ANOVA test on IBM SPSS V.25 and Microsoft Excel software licensed. The purpose of using the ANOVA test was to compare the average value of each group before and after being given treatment and test the difference in the post-test mean value between the experiment group and control group with the criteria for a testing significance level of  $p < 0.05$ .

**Results**

A good training program will affect the output of changes in the athlete’s physical ability performance. At baseline measurement, there was no significant difference between any of the physical characteristic variables Table 1. Thus, it provided an acceptable homogeneity among the groups.

Comparing pre-test and post-test parameters Table 2. The plyometric experimental group with active recovery and plyometric experimental group with passive recovery resulted in a significant effect comparison ( $p < 0.05$ ) on increasing VO2Max endurance, left-hand grip strength, right-hand grip strength, flexibility, speed, and leg power. In the control group, the comparison of significant effect ( $p < 0.05$ ) was on the strength of the right-hand grip, while the comparison of insignificant effect ( $p > 0.05$ ) was on VO2Max endurance, left-hand grip strength, flexibility, speed, and leg power.

Furthermore, according to parameter difference test post-test results of Table 3. Experimental and control groups showed that the experimental group with active recovery plyometric, plyometric with passive recovery, and a control group make a significant effect ( $p < 0.05$ ) on endurance VO2Max and leg power. While the differences

**Table 1.** Information on The Characteristics of Participants in Each Group (Mean±SD)

Variable	Experiment plyometric with active recovery (n=11)	Experiment plyometric with passive recovery (n=11)	Control Group (n=11)
	Mean±SD	Mean±SD	Mean±SD
Age (year)	21.8±1.78	21.7±2.53	21.4±2.30
Height (m)	1.70±0.06	1.71±0.06	1.72±0.05
Weight (kg)	71.1±13.5	63.8±10.1	67.4±7.76

**Table 2.** Parameter comparison of pre-test and post-test experimental group and control group

Variable Test	Group	Pre-test (n=11)	Post-test (n=11)	t	p
		Mean±SD	Mean±SD		
VO <sub>2</sub> Max Endurance	Plyometric with active recovery	43.9±3.18	50.6±2.02	-7.586	0.000
	Plyometric with passive recovery	49.0±3.70	51.9±2.89	-3.963	0.003
	Control group	46.2±6.66	45.7±6.16	0.837	0.422
Left-hand grip strength	Plyometric with active recovery	39.8±3.24	43.2±2.43	-6.983	0.000
	Plyometric with passive recovery	40.5±3.55	42.9±3.38	-5.157	0.000
	Control group	40.3±3.79	40.8±4.08	-1.376	0.199
Right-hand grip strength	Plyometric with active recovery	42.3±4.51	46.2±5.25	-3.793	0.004
	Plyometric with passive recovery	41.1±4.97	45.9±5.45	-8.820	0.000
	Control group	41.5±4.54	46.8±6.08	-4.537	0.001
Flexibility	Plyometric with active recovery	17.5±3.18	22.6±4.41	-5.916	0.000
	Plyometric with passive recovery	21.3±4.03	23.4±4.60	-3.266	0.008
	Control group	21.7±3.88	21.3±3.52	0.793	0.446
Speed	Plyometric with active recovery	4.59±0.31	4.32±0.43	4.441	0.001
	Plyometric with passive recovery	4.84±0.61	4.47±0.47	4.509	0.001
	Control group	4.68±0.36	4.71±0.31	-0.359	0.727
Leg power	Plyometric with active recovery	71.1±9.45	79.3±15.7	-2.946	0.015
	Plyometric with passive recovery	78.8±13.9	84.8±15.5	-3.854	0.003
	Control group	56.5±8.61	57.1±9.57	-0.715	0.491

**Table 3.** Parameters of difference in post-test results of the experimental group and control group

Variable Test	Group	Mean±SD	F	p
VO <sub>2</sub> Max Endurance	Plyometric with active recovery	50.6±2.02	6.888	0.003
	Plyometric with passive recovery	51.9±2.89		
	Control group	45.7±6.16		
Left-hand grip strength	Plyometric with active recovery	43.2±3.38	1.690	0.202
	Plyometric with passive recovery	42.9±3.38		
	Control group	40.8±4.08		
Right-hand grip strength	Plyometric with active recovery	46.2±5.25	0.072	0.931
	Plyometric with passive recovery	45.9±5.45		
	Control group	46.8±6.08		
Flexibility	Plyometric with active recovery	22.6±4.41	0.707	0.501
	Plyometric with passive recovery	23.4±4.60		
	Control group	21.3±3.52		
Speed	Plyometric with active recovery	4.32±0.43	2.466	0.102
	Plyometric with passive recovery	4.47±0.47		
	Control group	4.71±0.31		
Leg power	Plyometric with active recovery	79.3±15.7	12.145	0.000
	Plyometric with passive recovery	84.8±15.5		
	Control group	57.1±9.57		

are not significant, the effect ( $p > 0.05$ ) is found on the left-hand grip strength, right-hand grip strength, flexibility, and speed.

### Discussion

This study was designed through a quasi-experimental design approach which was carried out in a controlled manner. To obtain the best results, the purpose of this study was to examine differences in the effect of  $VO_{2\text{Max}}$  endurance, left and right-hand grip strength, flexibility, speed, and leg power of male judo athletes before and after being treated for eight weeks between the plyometric with active recovery (PAR), plyometric with passive recovery (PPR), and control group (GC).

The findings of this study confirm that treatment in the experimental group of plyometric with active recovery (PAR) and plyometric with passive recovery (PPR) resulted in a significant change effect on  $VO_{2\text{Max}}$  endurance, left and right-hand grip strength, flexibility, speed, and leg power. Meanwhile, the control group (GC) only compared a significant increase in the right-hand grip test results. The findings of this study support the conclusions of previous literature that there is a significant relationship between speed and  $VO_{2\text{Max}}$  endurance in aerobic and anaerobic energy systems to maximize judo athlete performance and adaptation to fatigue levels [23]. Furthermore, the findings carried out [24, 25] concluded, speed and leg power contribute to movement transfer techniques, fast throws, and handgrip strength; flexibility is needed to regulate an opponent's reach and distance.

This study conducted Çelik and Soyal [26] concluded that strength training carried out for six weeks caused significant handgrip strength and creatine kinase changes in judo athletes, and these changes came from duration scope, frequency, and severity training content. In addition, high-intensity judo training affects changes in heart rate, flexibility, and strength of the neck muscles, and adequate rest after exercise can help prevent injuries to judo athletes [11]. In addition, the findings of this study further confirm that there is a significant difference between the effect of plyometric training with active recovery (PAR), plyometric with passive recovery (PPR), and control group (GC) on  $VO_{2\text{Max}}$  endurance change and leg power. Meanwhile, there were no significant differences in handgrip strength, flexibility, and speed.

This study results conducted Péter-Zsolt Szabó et al. [27] concluded that repetition speed does not significantly affect the judo training period, and speed is not the main determining factor in judo training. The findings study Logeswaran [28] concluded, strength training carried out for eight weeks resulted in significant changes in the

leg power of judo athletes. Furthermore, Franchini et al. [29] concluded that the aerobic fitness profile is essential as a basis for maximal oxygen absorption ( $VO_{2\text{Max}}$ ), good recovery during rest periods, and is relevant to the performance of judo athletes. In addition, recovery can be an effective method in improving the performance of the physical condition of judo athletes, and the post-exercise recovery method currently widely used in judo training is using passive recovery with relaxation techniques that aim to relax muscle tension after exercise [30]. The findings of another study conducted Lesmana et al. [31] concluded that active recovery carried out by reducing 20% to <50% DNM using the walking or jogging method after high-intensity exercise will keep the hormone epinephrine secreted. The hormone epinephrine has a function as a guard for the heart muscle to keep contracting (systole) and not to suddenly decrease the heart's performance. In addition, active recovery by jogging for 10 minutes after doing anaerobic exercise will reduce 31.7% of lactic acid levels in the blood [32].

### Conclusions

Based on the results of an analysis that has been carried out, it can be concluded that the ability of  $VO_{2\text{Max}}$  endurance, handgrip strength, flexibility, speed, and leg power of judoka men experienced significant changes after being treated for eight weeks. Furthermore, the different test parameters confirmed that the experimental group was given the treatment, and the control group produced a significant difference in  $VO_{2\text{Max}}$  endurance and leg power. In comparison, no significant differences occur in handgrip strength, flexibility, and speed. Furthermore, the results of this study are expected to be a reference or reference for coaches to be able to design, implement, and develop plyometric training programs, as well as pay attention to the post-exercise recovery process both in active and passive forms that can affect the performance of judo athletes' physical abilities, and gain performance—maximum during the match.

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# The effect of menstrual cycle on anaerobic power and jumping performance

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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** There has been a significant increase in the participation levels of women in competitive sports in recent years. This has contributed to the increase of research on women's participation in sports and their health. The aim of this study is to investigate the effect of the menstrual cycle on anaerobic power and jumping performance.

**Material and Methods** In this study, 15 female athletes between the ages of 18-24, who have a regular menstrual cycle for the last 6 months. They have not used any hormone preparations, have not received any medical support in the last month. They are healthy and actively engaged in sports in university teams (basketball, futsal, volleyball) participated voluntarily. Wingate Anaerobic Power Test and Active Jumping Test applied to athletes during their menstrual phases (second day of the menstruation period) and follicular phases (14th day of the menstruation period). In the statistical analysis of the data, descriptive analyses of test measurements of athletes were calculated as mean and standard deviation. Whether there is a significant difference between the measurements taken on two different days was analyzed using the t-test in dependent groups.

**Results** It was determined that the anaerobic power and active jump performances of the participants had an effect on peak power, fatigue index and active jump performance between day 2 and day 14 values. Also, there was a statistically significant difference between these values ( $p < 0.05$ ).

**Conclusions:** This situation can be explained as a result of the hormonal changes in the menstrual period of the athletes and the effects of psychological factors specific to this period.

**Keywords:** menstruation, performance, sport, anaerobic power, active jumping.

## Introduction

Women have a different structure compared to men with their physiological, anatomical, psychological and special conditions. The difference in these structures greatly affects the sportive performance of both breeds. The biggest physiological difference that separates women from men is the menstrual cycles under the control of the hormonal system [1]. In addition, when both sexes are examined in terms of anatomical structure, there is a 5-10% difference between them, while this rate varies around 10-20% in terms of their physiological structures [2].

In recent years, there has been a significant increase in the participation levels of women in competitive sports. This situation has contributed to the increase of research on women's participation in sports and their health. According to researches, it has been stated that varying hormone levels within the menstrual cycle can affect sports performance [3-6].

Female athletes who have regular menstrual cycles do not need to correct their menstrual bleeding for maximal performance in sports branches that require strength and power, and in sports where high levels of aerobic-anaerobic capacity are required. It is very important to organize mental and physical functions in a balanced way for maximal physical performance. Since the effects of menstruation on sportive performance are remarkable, there have been many studies in the literature examining

the relationship between menstruation and sports [7-11].

Studies on the subject in the literature have shown that menstruation does not have a great effect on the organism and women can easily participate in sports activities. In fact, it has been observed that many female athletes performed successfully and achieved significant degrees during their menstrual periods [12]. In addition, it is known that irregularities of the menstrual cycle are often seen in endurance athletes [13]. In a study conducted on adolescent athletes, it was reported that menstrual disorders are quite common [14].

In the findings of these studies, it was determined that it was not revealed exactly whether menstruation affects sports performance in women. It is very important to determine how the menstrual period affects women's sports performance and their capacity to use motor characteristics. In this context, this research was conducted to investigate the effect of the menstrual cycle on anaerobic power and jumping performance.

## Material and Methods

### Research Group

In this study, 15 female athletes between the ages of 18-24, who have a regular menstrual cycle for the last 6 months. They have not used any hormone preparations, have not received any medical support in the last month. They are healthy and actively engaged in sports in university teams (basketball, futsal, volleyball)

participated voluntarily.

Prior to the study, 18 June 2021 (Decision number: 60116787-020-64733) ethics committee approval was obtained from Pamukkale University Non-Invasive Clinical Research Ethics Committee.

Participants were given detailed information about the risks that may be encountered in the study, and the voluntary consent form was read and signed. In addition, participants were asked to sleep for at least 8 hours before each test, to avoid intense physical activity the day before and on the test day, and to quit alcohol and caffeine intake 24 hours before each test.

*Procedure*

On which day of the menstrual cycle of the subjects, the subjects were asked verbally in advance and the measurements were planned based on the information provided by the subjects. In this study the measurements were taken in the menstrual phase, which is the second day of the menstruation period, and the ovulation phase (ovulation period), which is the 14th day. The menstrual calendars of the subjects were recorded one month before the measurement started.

*Exclusion Criteria*

- \* Using a menstrual regulator,
- \* Disabled or sick on the day of measurement,
- \* Participants with suspected pregnancy were excluded from the study.

*Data Collection Tools*

*Anthropometric Measurements*

Participants' height was measured with a wall-mounted stadiometer (Holtain, England), which can measure with an accuracy of 0.1 cm, and body weight with an electronic scales (Tanita TBF 401A, Japan) that can measure with an accuracy of 0.1 kg.

*Performance Tests*

*Active Jumping Test*

A total of 8 minutes of warm-up protocol was applied to the participants including 5 minutes of low-tempo warm-up and 3 minutes of dynamic flexibility movements for lower extremities before the test. Later, the active jumping performances of the participants were measured with Smart Jump. The athletes climbed on the mat in light sports clothing (tights and T-shirt) and made a quick downward slump from the upright position, jumped upward with maximum force and were placed back on the mat. This jumping was repeated 3 times. The best and average jump height and the best and average hovering times were read and recorded from the computer program as the hops time in the air in milliseconds (ms) and height

in centimeters (cm).

*Wingate Anaerobic Power Test*

A pre-test warm-up protocol was applied to the participants. After the participants sit on the bicycle ergometer, the appropriate sitting height was set. Warm-up included pedaling at 60-70 RPM (RPM) for 4 minutes. The participant applied 3-second maximal pedaling protocols 1 minute 30 seconds after the beginning of this warm-up period and 2 minutes and 30 seconds later. By observing the maximum RPM speed of the participant at these maximal pedal speeds, the required saddle release pedal speed for the test was determined. After the warm-up was finished, the participants were given a 5-minute recovery period. Then, when the participants reached the maximal pedal speed within the first 5 seconds, the weight seat was automatically released and they pedal at the maximum speed on the bicycle ergometer against the predetermined constant load for 30 seconds to provide the highest mechanical power. During the test applied, measurements were made automatically every five seconds at six equal time intervals and the relative power data were recorded as maximum anaerobic power (W / kg), average anaerobic power (W / kg) and minimum anaerobic power (W / kg).

*Statistical Analysis*

SPSS 22.0 for Windows package program was used in the analysis of the data obtained. Descriptive analyzes of the participants' basic characteristics were calculated as mean and standard deviation. Whether the data showed normal distribution was evaluated using the Shapiro-Wilk test. Whether there is a significant difference between the measurements taken on two different days was analyzed using the t-test in dependent groups. The level of significance was set at  $p < 0.05$ .

**Results**

Descriptive characteristics of the participants are shown in Table 1.

As a result of the measurements made, it was determined that wingate anaerobic test and active jump performances of the participants had an effect on peak power, fatigue index and active jump performance between day 2 and day 14 values. There was a statistically significant difference between these values ( $p < 0.05$ ). In the study, when the performance values in different phases of the menstrual cycle were compared, it was found that the anaerobic performances and jumping performances of female athletes were higher on the 14th day, that is, during the ovulation period (Table 2).

**Table 1.** Descriptive characteristics of the participants

Variables	N	Mean ± Sd	Min. Value	Max. Value
Age (years)	15	21.27 ± 2.05	18	24
Body weight (kg)	15	60.40 ± 5.88	50,20	72,50
Height (cm)	15	167.40 ± 4.69	160,44	175,78

**Table 2.** Anaerobic power and jump performance menstrual phase difference analysis table

	Parameters	Mean $\pm$ Sd	t	p
Anaerobic Power	Peak Power (W) 2 <sup>nd</sup> day	873,96 $\pm$ 98,29	-2,80	0,001*
	Peak Power (W) 14 <sup>th</sup> day	950,46 $\pm$ 83,31		
	Average Power (W) 2 <sup>nd</sup> day	612,45 $\pm$ 88,86	-1,33	0,20
	Average Power (W) 14 <sup>th</sup> day	647,68 $\pm$ 97,41		
	Min Power (W) 2 <sup>nd</sup> day	344,90 $\pm$ 98,56	-1,79	0,09
	Min Power (W) 14 <sup>th</sup> day	399,89 $\pm$ 71,58		
	Fatigue Index (%) 2 <sup>nd</sup> day	60,73 $\pm$ 9,46	3,19	0,01*
	Fatigue Index (%) 14 <sup>th</sup> day	51,19 $\pm$ 10,82		
Jumping	Active Jumping (cm) 2 <sup>nd</sup> day	25,67 $\pm$ 4,92	-3,80	0,00*
	Active Jumping (cm) 14 <sup>th</sup> day	27,39 $\pm$ 5,82		

(p<0,05)

### Discussion

The menstrual cycle affects many parameters in metabolic, cardiovascular and respiratory aspects besides athletic performance due to the changes it causes in hormonal structure. Since there are many factors that affect athletic performance, researchers have also done a lot of research on performance changes during menstrual periods. When the studies in the literature are examined, it is seen that the findings of the research examining the relationship between sportive performance and menstrual cycle periods are contradictory [15]. In some studies, there was no significant change in sports performance parameters during menstruation [16-18], on the other hand, in some studies, it was determined that there was an increase or decrease in sports performance elements during this period [19-21].

According to the findings of the study, it was determined that wingate anaerobic test and active jump performances of the participants had an effect on peak power, fatigue index and active jump performance between day 2 and day 14 values and there was a statistically significant difference between these values (p<0.05). In the study, when the performance values in different phases of the menstrual cycle were compared, it was found that the anaerobic performances and jumping performances of female athletes were higher on the 14th day, that is, during the ovulation period.

Looking at the studies parallel to the findings of our study, Masterson [22] found a difference in the wingate anaerobic power test performed in the follicular phase and luteal phase in his study on 32 college athletes in terms of anaerobic capacity between phases and the maximum power values they can produce. According to the test

results, anaerobic capacity and maximum power values were higher in the follicular phase compared to the luteal phase. In a similar study by Karacan [23] it was reported that premenstrual syndrome, in which physical, psychological and behavioral changes are experienced in the second half of the menstrual cycle three days before menstruation, negatively affects attention, concentration, motivation, speed and quickness, which are among the determinants of performance. Colakoglu et al. [24] investigated the relationship between exercise-menstruation and training age-menstrual cycle pattern in a survey they conducted on 56 active female volleyball players, and as a result, they found that exercise did not affect menstruation and that menstruation psychologically affected sports activity. Karacan et al. [25] in their studies investigating the relationship between menstruation and different branches of football, basketball, handball and field hockey, among 133 women athletes from the Turkish First League and Turkish Super League, it was stated that menstruation physically affected sportive activity as well as sports activity. Also reported that it affects the menstrual cycle. Kucuk and Ozgider [26] in the survey they conducted on 72 volunteer women volleyball players, the athletes' menstruation; They reported that it affected their daily life and physical performance. In a study conducted by Akkus [27] on athletics and volleyball athletes, it was found that the strength, speed and endurance performances of athletes differ in different stages of the menstruation period, and these changes were found to be at a statistically significant level. Smith et al. [28] showed that menstruation was affected by high intensity exercises in the responses to exercises of different intensity in 3 different periods of menstruation. Aras et al. [29] examined anaerobic power

values according to the phases of the menstrual cycle in their study. For the 9 volunteers who participated, they found that the anaerobic power values did not change in the follicular, ovulation and luteal phases of the menstrual cycle.

There are studies in the literature that do not parallel our study findings. In a study conducted by Higgs and Robertson [30] it was found that there is no change in the sportive performance of female athletes before and during menstruation. Ertas and Ersoz [31] reported in their study on 28 female athletes with 14 regular and 14 irregular menstruations, and the best degrees of athletes were at the beginning of menstruation. Cakmakcı et al. [2] applied wingate test to female university students on the 2nd and 14th day of their menstrual cycle and reported that anaerobic performance obtained in menstruation and follicular phases was not different as a result of the research. Dolek and Ersoz [32] in their study on swimmers, showed that athletes with regular menstruation periods are best 25 meters They reported that they demonstrated their swimming performances on the 2nd and 15th day of their menstrual cycle, respectively, and the worst degrees occurred on the 26th day of the cycle, and there was a statistically significant difference between the results. In another study conducted by Bushman et al. [33] anaerobic power in moderately active women between menstrual period and luteal period after the wingate test in both normal menstrual cycles ( $n = 7$ ) and oral contraceptive users ( $n = 17$ ) It has been determined that there is no difference. Tsampoukos et al. [34] in their study on 8 healthy female athletes, reported that the mean peak power and mean power values did not differ statistically between phases. Hazır et al. [35] found no effect of menstruation on repetitive sprint performance and recovery rate in the repetitive sprint test and recovery rate measurements they performed in the midfollicular phase and luteal phase on 11 female athletes with regular menstruation. In the study conducted by Stefanovsky et al. [36] on judo athletes,

the participants were applied the wingate test and their performance values in different phases of the menstrual cycle were compared. It has been reported that there is no statistically significant difference between the performance values. Moraleda et al. [16] in their study on 13 female triathletes, performed half squats with 50% of their 1RM on athletes. It has been reported that the performances of the athletes in 3 different menstrual cycles did not make a significant difference. In a study conducted by Guler [37] on volleyball players, it was reported that the menstrual cycle did not have any effect on the flexibility, muscle strength, anaerobic power and sprint performances of the athletes. The period of menstruation, physiological changes in body weight, edema in the abdomen, wrists and ankles, pain in the abdomen and waist area, psychological anxiety, irritability, minor depressive states, and mental depressions are clinical symptoms of premenstrual syndrome. Physiologically and psychologically negative effects are thought to affect performance negatively [23].

### Conclusions

As a result, it can be said that physiological changes during menstruation should be known by trainers and it should be taken into consideration that these changes may affect sportive performance. In addition, in new studies on the subject; the number of phases measured, the number of similar tests and subjects can be increased. In other branches where the anaerobic energy system is dominant, the measurement can be made by applying the same test protocol and the results can be compared.

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### Conflicts of Interest

The authors state no conflicts of interest.

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# Social representations of physical education teachers concerning the game: a qualitative study in Chile

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## Abstract

**Background and Study Aim** The objective of this research was to determine the social representations of the game in physical education teachers belonging to the Chilean educational system, searching for the sense and meaning given by the educators to the game aspect.

**Material and Methods** The study sample consisted of 14 physical education teachers, who were chosen by the convenience sampling method. Semi-structured interviews were used to collect data from the participants, maintaining gender equity. The analysis of the data obtained was by means of content analysis and the NVivo 11 program was used to process the data.

**Results** Our research indicates that of the categories analyzed, the highest was the role of the game (22.29%), demonstrating the relevance given by teachers to the game in the development of meaningful learning. On the contrary, the category characteristics of the game (17.42%), describe how teachers visualize the contributions of play at the educational level, in this sense, the role of the game goes beyond motor contributions, but also provides tools for social and cognitive development.

**Conclusions:** For the teachers, the game promotes autonomous and proactive actions of the students, which will be beneficial to understand that playfulness in education implies not to put in contradiction the rational and emotional faculties. This comprehensive view is called full attitude, and it is a relevant step toward the understanding of the game from a complex perspective. In this area, it is evident that, in the social representations of the participating teachers, the game constitutes a natural environment in which children develop, where the physical education teacher should create an environment that facilitates the game, facilitating the expression of autonomy, freedom, creativity, and playfulness.

**Keywords:** game, playfulness, physical education classroom, learning.

## Introduction

Children's play is an activity in which the child sets in motion the mechanisms of imagination, the way of seeing the world around them, transforming it, developing creativity and giving the possibility of opening up to others [1-4]. Whether at school or in the family environment, children devote part of their time to play, depending on their ages and preferences. In all cases, the game contributes to the development of the child's personality, which should be taken into account in primary education classrooms and by physical education teachers in particular [5-7]. The game involves enjoyment, not only for the children but also for those who guide the game. The effectiveness of play for learning is related to the positive emotions it generates since actions are mobilized by an intrinsic reward [8-10].

In this context, the game produces pleasure, is motivating, and generates positive emotions, since, if children did not have this internal drive, guided by an intrinsic reward, they would not invest time in this activity. Consequently, play is an activity that is done for the pleasure of doing it, it does not have a utilitarian goal, but, in the long run, it will be very useful for life in society

[11-13]. The literature, reports that when investigating the needs of the child's personality and corporeality, the game is part of the essential activities of human nature, being characterized as a spontaneous, functional, and satisfactory action, a process that allows the child to enter an illusory and imaginative universe, stimulating greater self-control, since he/she will have to deal with conflicts derived from social rules, better controlling his/her impulses through self-regulation [14-16]. However, few parents and teachers are aware of the importance of play for the healthy physical and psychological development of children. Sometimes it is limited to a pastime, disconnected from more important functions than the entertainment of the youngest; however, through play, children manage to control their distress to express their feelings and fantasies, permeating the real and the imaginary [2, 3, 6].

Playful activity, consisting of play and fun, is a pedagogical tool for the performance and full development of students in the elementary classroom. In the present research, the game is an educational means that allows the development of physical, psychological, social, and spiritual potentialities, from within the person being educated, these constitute the support of all learning in the elementary classroom [3, 8]. The game at school provides

unique moments of fun, joy, relaxation, and a commitment to learning and responsibilities [17, 18]. For authors such as Aras [1] and Athey [2], play is a necessity in the life of human beings, throughout their lives and not only as entertainment, or moments of pleasure, but moments conducive to the development of creativity, socialization, reasoning, motor coordination, cognitive, affective and psychomotor domains. The game can be seen as a bridge that connects reality with the world of imagination, since, through the child's play, adults can understand how he or she sees and constructs their world, what problems they face, how they would like their life to be, and make their concerns known [4, 11, 19, 20]. Children often express through their actions what they find difficult to put into words, in other words, play is their language that deserves respect, even if it is not fully understood.

From the theoretical, the study is based on the Social Representations Theory (SRT). This theory provides an understanding of the social thinking of teachers, whenever practices happen in school institutions are conditioned by beliefs, values, models, and symbols, which social psychology calls social representations [21-23]. The analysis of SRT allows reflecting on the pedagogical practice developed in schools, and specifically in the classroom, allowing teachers to ask themselves about their practices and the possible effects of their pedagogical work on their students' learning [24-26]. According to Abric [27], this knowledge is constituted by lived experiences and by the circulation of information about a social object among the elements of a given social group [28-30]. The analysis of social representations allows us to reflect on the beliefs and practices held by teachers regarding the constructed game in the physical education classroom.

Using the game in educational situations not only provides a real means of learning but also allows perceptive and competent adults to learn about children and their needs [17, 31-33]. In the school context, this translates to teachers being able to understand where children are in their learning and overall development, which in turn gives educators an indication of how to promote new learning, within the affective, cognitive, and motor domains [2, 8, 11, 34]. According to the above-mentioned, the teacher's role in playful development has to be based on trust, affection, encouragement, praise, limits, placed in a sincere, clear, and affectionate way, allowing interaction between the adult and the children. The teacher must be able to respect and nurture the child's interest, affords him/her possibilities to be involved in the process, or else the richness that play represents will be lost [4, 6, 12, 35, 36]. When playing, the teacher should create a bond with his or her student and allow a climate of safety to be established, he or she should set a goal for each activity and organize the time to be used.

In this context, the representations about the game by teachers will allow understanding of the sense and meaning given by physical education teachers, to the playful component that appears in the game, revealing how teachers conceive aspects such as leadership, obedience

to rules, collaboration, competition, respect and tolerance in the physical education classroom [37-40]. This requires understanding that the game is a necessity, regardless of age, and should not be considered as entertainment, but as a learning process. Consequently, from the playful perspective, it is understood as the need of human beings to communicate, to feel, to express themselves, and to produce emotions oriented to entertainment, fun, recreation, which leads to a real generating source of emotions [41]. The game and playfulness contribute to good physical and mental health, facilitating the process of socialization, communication, and construction of knowledge, in addition to the full and integral development of the individuals involved in the teaching-learning process.

*The objective* of this research was to determine the social representations of the game in physical education teachers belonging to the Chilean educational system, searching for the sense and meaning given by the educators to the game aspect.

## **Material and Methods**

### *Participants.*

The participants of the study were physical education teachers from public primary schools in the province of Talca, Maule Region, Chile. Fourteen semi-structured interviews were conducted maintaining gender equity (7 women and 7 men). Participants who met the inclusion criteria of the study were involved. The inclusion criteria were: physical education teachers working in the city of Talca, Maule Region, Chile; at least three years of professional experience in the school system; public school teachers working in primary education. Exclusion criteria were defined as: teachers with fewer than three years of professional experience; general education teachers. Theoretical saturation was achieved when reaching saturation of the response alternatives.

### *Research Design.*

This research is a qualitative study, based on the interpretive-comprehensive paradigm [42], which was performed in the region of Maule, Chile, between April and September 2020. Before data collection, the researchers obtained written informed consent to ensure the confidentiality of the names of the individuals, taking into account privacy and emphasizing voluntary participation. Participants were informed about the purposes of the research and their authorization was requested to record the interview, to safeguard ethical aspects. The interview was performed via Zoom or Skype, due to the sanitary emergency the country is going through, to maintain the sanitary conditions established by the authorities. In addition to using an audio recorder, manual observations were made to clarify the possible intentions of the teachers at the time of the interview, which had an average duration of 60 minutes, rigorously following the Helsinki protocol for research with human beings. The interview was selected as a methodological resource due to its flexible characteristics, understanding that the application of the technique allows an interactive

process between the researcher and the interviewees [43]. The interview guideline contemplated questions such as the following: what is your work experience with respect to the game in the physical education classroom? What is the most recurrent behavior of children in the classroom when you propose play? How do children who present behavioral problems when they play share themselves in the classroom? What would be your greatest strengths for working with play in the physical education classroom? What would be the greatest strengths to work with the game in the physical education classroom? How do you approach the didactics of the game in the classroom from a pedagogical approach? Given your experience as a teacher, what recommendations would you make to the Initial Training (IT) to address the playful perspectives of the game?

#### *Qualitative Analysis*

To examine and interpret the data, content analysis was used, which constitutes a research methodology with systematic descriptions that allow an interpretation and understanding of meanings [44]. The content analysis made it possible to identify common recurring issues and to determine the main themes that summarize the opinions collected by the study participants. Content analysis was applied to analytically examine the transcribed material from the individual interviews and focus groups, dividing the text into relatively small content units and subjecting them to descriptive treatment, with the idea of converting the phenomenon into data that can be scientifically treated and building with them a body of knowledge about the social representations of teachers regarding the game in the physical education classroom. Following the guidelines of content analysis, the transcripts of the interviews and focus groups were read, and the recordings were listened to repeatedly to find the units of meaning, in terms of codes, inductively. It should be noted that the dimensions were specified as primary categories, and were obtained from the review of the theoretical framework [45]. Under these, dimensions were grouped as codes and then the categories were obtained from the systematic and repeated reading of the participants' reports. NVivo 11 software was used for data processing.

## **Results**

The model is presented below, whose macro category focuses on the perception of the game construct by the physical education teachers. In the table, two previous categories emerge that evidence the representation of the game by the interviewed subjects, that is, didactics of the game and playful perspective of the game; each story presented has a code that expresses the interview (I), the number (no.) and the corresponding page (p.).

*Previous category: Didactics of the game, primary category: Role of the game*

The category "Role of the game" has 22.29% of the testimonies in the study, the highest of all, demonstrating the relevance given by the studied teachers to the role of the game in the development of meaningful learning in children. This category defines how a group of people with different academic backgrounds and professional experiences, focus on the fact that the game is a fundamental activity not only in education, but also in life.

"The game accompanies us at all ages from we are children until we are adults, where the playful part is lost a little in our daily life, something I do not agree with since the game would help us to regulate and better channel our actions. Making better decisions, facing failures in a better way, etc. In short, there are many strengths that the game provides, such as regulating your energies and learning from healthy competition." (E, no. 5, p. 1)

"I see the game as an activity, a process, that helps a lot in so many areas of a person, in the motor, physical, emotional, and cultural development, with the typical games of a country, games that have been played for many years and that help children culturally, they are a way of passing on traditions and customs, and that favors the inclusion of everyone in the classroom." (E, no. 1, p. 3)

After reviewing the testimonies, it is understood that the game is transversal and contributes to all the areas in which the subject develops. The game is the best way for children to unfold their potential and be able to understand them. According to the account of the teachers

**Table 1.** Systematization Model

Macro Category	Previous Categories	Descriptor	Primary Categories	Frequency
Game/Learning	Game didactics	Category that describes the strategies and methodologies of the game used by the teacher as a learning tool.	Game role	22, 29%
			Teacher role	6, 62%
	Playful perspective of the game.	Category that gathers the teacher's perception of the proposal of the game in the classroom and education in all its areas.	Learning	16, 37%
			Student's actions	16, 37%
			Gaming benefits	6, 62%
			Game characteristics	17, 42%

Source: Own elaboration

studied, when children play, they expand their bodily capacity, their perception, their relationship with others, they discover the world and know the laws and rules.

“For me, the game should always be throughout everyone’s life, and it depends on the stage the child is in. I think that right now the concept of the game has been lost very much and dangerously at even pre-basic ages.” (E, no. 6, p. 2)

Making the game the object of intervention in physical education classes is a useful way to assume another rationality for this space-time, which associates the interests and needs of children. The game is a human activity, in which imagination, fantasy, and reality interact in the production of new possibilities of interpretation, expression, and action by children, as well as new possibilities of building social relationships with other subjects.

*Previous category: Didactics of the game, primary category: Teaching role*

The category “Teaching role” has 6.62% of the testimonies and is within the primary category related to the role that the teacher must accomplish at the moment of proposing the game within an educational context, and how this term is inserted within the initial training of physical education teachers.

“The importance of the game, the benefits it has... in fact, I would make early childhood motor skills mandatory in the major. At least in physical education. I think it is too important a subject that is not given the importance it should have. It would help us work on collaboration, empathy, respect, and self-esteem through the game.” (E, no. 8, p. 5)

“There is a great lack of educating others about the importance of the game, and I say others, with colleagues, or the parents themselves, that when sometimes play is mentioned to them, they associate it with something basic, that does not have much relevance. I think that there is a lack of understanding of the game as a pedagogical resource, that there is no criticism from those who do not understand the concept of the game and its importance in the development of students”. (E, no. 4, p.3)

According to the narratives, the teacher should be someone who gets involved with the students and, at the same time, gives importance to the game. The teacher must focus on the dynamism of the process and the integration of knowledge, observing and documenting individual and group processes. In the account, the role of Physical Education in the school context, its uniqueness, meaning, and social function can be observed.

“You are a teacher and the students are students, but you have to be part of the class, that is, you are a guide, a model practically for the children, and if you do not feel part of the class for a child, it is demotivating.” (E, no. 3, p. 4)

Physical Education is about the relationship of a domain of knowledge that focuses on the dimension

of doing; nevertheless, it includes the conceptual and attitudinal dimension that the teacher must establish as the central focus of teaching actions and, consequently, use the game as a pedagogical resource for the development of these dimensions.

*Previous category: Didactics of the game, primary category: Learning*

Within the primary category related to learning, it is crucial to mention how the game is present in the children’s perception of this process is subjective, since they have different learning rhythms and methods. The physical education class is presented as a stage where they receive other stimuli that many times favor deconcentration. This category represents 16.32% of the analyzed reports.

“In individual game, it could be said that even the student does it a little out of competition with the classmate next to him. In the classroom, competitive play is very frequent, but not in the sense of competition. For example, when they do an exercise badly and the team wins, I give the point to the other team because they did not follow the instructions of the exercise, or they skipped such and such material or stepped outside the mat., etc.” (E, no. 11, p. 5)

According to the narrative, part of the learning comes from how the game is applied and the variants that are incorporated into it. Learning is built from meaningful learning experiences that transcend and extend across more than one domain.

“Children are competitive, sometimes it is not bad to give the competitive part, as long as the recreational and value aspects are not left aside, but children themselves have that competitive part and in children, it is more evident, that is why we must insist on respecting the rules, to know how to win and how to lose.” (E, no. 2, p. 2)

“The idea is to vary from the beginning, from individual work to teamwork, because children, especially when they are young, have a hard time working as a team, for example, in first grade, there are fights in all classes because they do not know how to share, they do not know how to work as a team, so the game helps us for teamwork and cooperation, including the gender issue.” (E, no. 14, p. 6)

Learning does not take place exclusively in the formal school system, since children can contribute their cultural capital, their interests and their scholastic concerns at any time and in different contexts. What could be more interesting and stimulating than learning through play? It is possible to build a pedagogy of play in the school, effectively and efficiently connected to the school classroom.

*Previous category: Playful perspective of the game, primary category: Student’s actions*

This term was selected within the playful perspective of the game and reaches 16.32% of the narratives. This category is very important since it develops how the teachers perceive that the student behaves when game

instances are proposed. Teachers evidenced different realities, from frustration, to, in other cases, extreme happiness.

“They wait a lot for that moment when they can play and as a teacher, you know that, so you have to motivate this type of students, so that they become positive leaders in the game space, with full autonomy.” (E, no. 10, p. 3)

“My students expect physical education class, and you have to respond to this expectation of the children, but always with the conviction that they will learn, therefore, one has to take advantage of this instance of more freedom in physical education, to teach them from the point of view of cooperation with the other partner through educational games.” (E, no. 7, p.2)

According to the teachers’ testimonies, children perceive the game as an instance of recreation and that, in those games where there is collaboration, social skills are generated which, although the children do not realize it, will be very useful to them in their development as integral persons with values. Taking into account that social skills are strategies that children learn and that allow them to behave appropriately in different environments and help them to initiate or manage social interaction in different environments and with a number of people, they should be taught in the early childhood environment, since it is in this period that children learn about behavior and social expectations with the game taking on a fundamental role.

“For my students, the physical education class is happiness, as if the children “explode” with happiness. They wait a lot for that moment, to be able to develop it. They know it is their moment because they will be able to play their games, they will be able to develop differently, it will be from the proposal that they will generate.” (E, no. 13, p. 5)

The game is a means for children to adjust their behavior to behaviors that favor their coexistence and life in society. It takes up play as a common denominator at school age, being one of the most effective mediating activities to transform certain evolutionary achievements into habits and instrumental skills at the service of other, more complex ones.

*Previous category: Playful perspective of the game, primary category: Benefits of the game*

This category has 6.62% of the totality of the narratives in the study. This category concerns the teacher’s perception of how the implementation of play in the physical education classroom benefits students, especially those with socioemotional problems.

“I use the game as a diagnosis, with the diagnosis I realize which child presents some signs of not wanting to share, or which child is shyer, which child is more skilful, sometimes in the same game.” (E, no. 12, p. 3)

“From my experience at school, the game for children with social-emotional difficulties is

very useful, because, through different didactic strategies, they feel involved, when you give them responsibilities in the game, as a leader, for example, they play a very important role, and that encourages them.” (E, no. 7, p. 1)

According to the statements, the implementation of the game in the physical education classroom has many benefits for students, especially for those who have some level of socioemotional difficulties. The game provides the expression of positive emotions and the opportunity to canalize and control the negative ones, in what is called social and emotional learning.

“Some of my students have difficulties at home, those who are insecure, so through the game they can improve that part, self-improvement, self-esteem, confidence, solidarity, hygiene habits. Everything is incorporated from the transversal and attitudinal point of view.” (E, no. 1, p. 3)

In this context, learning processes are framed in environments where emotions are key. A safe, affective environment, without fear, such as the one that favors the game, is the one that allows friendly relationships that expand our areas of understanding, thus fostering the pleasure of learning, which will propitiate the full development of the potential of each subject.

*Previous category: Playful perspective of the game, primary category: Characteristics of the game*

The category “Characteristics of the game” describes how the physical education teacher visualizes the contributions that the game delivers to the children at an educational level and how it can become a learning enhancer in other subjects, transforming education into an integral collaborative work for the benefit of the student. The stories represent 17.42% and point out:

“You observe them, and you realize how many games they come up with, they relate it to their motor expression, they act, they chase each other on horseback, that is, at that moment, which is not a game guided by an adult or teacher, I feel that it is the period of greater freedom for children, to develop their imagination, their creativity. And if they have rules, they are the ones who incorporate them or create them. So, the game is learning, it is not only a means to, but it is rather an objective, the objective that they play.” (E, no. 5, p. 2)

“The game is a moment of entertainment that generates a moment of well-being for the children, a participatory moment where they collaborate with their classmates, they have fun, there is a social aspect that is also affected and the children like to play, so it is a good resource to stimulate the class and get through the class until the end.” (E, no. 12, p. 4)

According to the teachers’ statements, the integration of games not only brings motor benefits to the physical education classroom, but also provides the child with tools for social and cognitive development. Therefore, it is important to articulate physical education, and the game

in particular, in other subjects and learning areas; in this sense, areas such as language and mathematics should be articulated and connected with diverse motor expressions. In the account of the subjects investigated, it is observed that the role of the game in Physical Education is of utmost importance, since it strengthens collaborative and social aspects, favoring the integral development of the child. Furthermore, it is presented in the school context as an enhancer of learning for other subsectors; nevertheless, this relationship of the game learning is still not valued in the educational environment, being that the game is used by the teacher as a means to achieve an atmosphere of entertainment and motivation within the class.

### Discussion

Using the game in educational situations not only provides a real means of learning, but also allows adults to learn about children and their needs. In the school context, this means that teachers can understand where children are in their learning and overall development, which allows educators an indication of how to promote new learning within the affective, cognitive and motor domains [5, 31, 32]. In this context, the physical education teacher should provide free and directed play situations, satisfying the learning needs of children. The teacher could be called an initiator and mediator of learning, as play becomes a pedagogical tool for the deployment of content in the classroom [8, 17]. In this line, the social representations that emerge from the key informants' discourse respond to this idea, since it is a perspective that is, at the same time, reconstituted by school physical education teachers [4, 46, 47]. This represents how each physical education teacher approaches the game in his or her pedagogical practice, since the game in primary schools is manifested differently; in other words, as a pedagogical resource or as a recreational activity, depending on the pedagogical intentionality of the teacher [12, 35].

The findings reported by the present study reveal that the physical education teacher can use different techniques to apply the contents and, even so, introduce the games for a better development of the classes and achieve its objective [40, 48, 49]. The physical education teacher can use different techniques to apply the contents and, as such, introduce the games for a better development of the classes and achieve its objective [40, 48, 49]. If the games are properly presented, the educational process will be satisfactory for all involved, since the playfulness influences the educator's teaching factors and also favors the students' learning [7]. Therefore, the game and playfulness are techniques that can be used to achieve the success of the subject's education, since the child will feel as a constructor subject of his training and will take learning to the context beyond the school space [1, 33, 50]. The teachers interviewed emphasize the importance of cooperation through play, which favors healthy competition, to work on autonomy, self-knowledge, self-criticism and self-esteem, inclusion, respect for rules, knowing how to win, knowing how to lose, and the gender question.

In terms of the previous category "Didactics of the Game", this is constituted from the primary categories role of the game, teaching role and learning, which coincident with the literature in the role that the game plays in the physical education classroom through the studies of Balan and Shao [5], Hortigüela Alcalá and Hernando Garijo [7], Barba-Martín, Bores-García [33] and Gil-Arias, Harvey [51]. These studies show that teachers value play in terms of learning and socialization. On the other hand, the perception that one of their contributions is learning with pleasure does not ensure that they know how to proceed in practice, to value the game in its origin, respecting its characteristics, which is to be a free, unpredictable, symbolic, regulated and well-defined action in terms of space and time of realization.

The category "Playful Perspective of the Game" is composed of the categories student's actions, benefits of the game and characteristics of the game, in which the teachers give an account of how the playful aspect is approached in the physical education classroom. In this context, it is presented how educators resolve the contradiction that arises when they propose to use games to teach certain curricular contents, given that one of their characteristics is the priority on the process of playing, and not on its effects or results. This is one of how the game and the playful perspective have been brought to the school, since it is considered promising for making learning and teaching meaningful [8, 11, 34, 51]. In the interviewees' accounts, it is observed that the game is one of the most important ways in which children obtain essential knowledge and competencies. Consequently, they value environments that favor play, exploration and hands-on learning. This is because development and learning are complex and holistic; however, all areas of development, including motor, cognitive, social and emotional competencies, can be encouraged through play, as shown in studies by Athey [2], Hoffmann and Russ [6], Hortigüela Alcalá and Hernando Garijo [7], Colliver and Veraksa [17], Abad Robles, Collado-Mateo [31] and Pesce, Masci [52]. In fact, in playful experiences, children use at the same time a whole range of competences, an issue that occurs frequently in the physical education classroom.

In this sense, teachers report that play activities, when well-planned, foster children's development and learning competencies more effectively than any other school activity. Along these lines, the literature reports that, through play, children learn to forge bonds with others, and to share, negotiate and resolve conflicts, in addition to contributing to their capacity for self-affirmation. The game also teaches children leadership skills, in addition to relating in groups, coping with social challenges and overcoming their fears [12, 19, 53]. In short, the student's actions are favored to the extent that the teacher proposes the game as a learning resource and as a socialization tool.

### Conclusions

The game, as an activity that promotes autonomous interaction, is a process that generates complexity and

has the potential to develop students' autonomy and proactivity. Therefore, the game can be valued as an instance of autonomy and proactivity development, as it proposes actions with sense and meaning. At the same time, the game has the potential to promote values such as listening, conversation and collaboration, since it is a tool and rather an excuse for conversation. Understanding the place of playfulness in education also implies not putting in contradiction the rational versus the emotional faculties, since in the playful spirit of a child everything is present and connected, things are not yet separated, as they will later be separated in the intellectual, the emotional, the volitional, science, art, religion, etc. This integrality is called the full attitude of children in the game, and it is a relevant step toward the understanding of the game from a complex perspective.

According to the social representations of the teachers interviewed, the game is the natural environment in which children develop and develop. The study reports that the physical education teacher should create an environment that facilitates play, that is, a moment in which autonomy, freedom, creativity and playfulness are expressed. This is because, in order for children to play with greater involvement, the central function of the teacher is to become part of this system, which implies bringing out the playful spirit that children carry within them. The above, in the perspective that the game, with its spaces and objects, is the activity of childhood that allows the process of progressive adaptation to the world to occur, since in exploration and free play the impulse to know arises spontaneously. On the contrary, accelerating development, skipping stages, focusing primarily on the achievement and acquisition of "cognitive" learning, has an inhibiting effect on this natural impulse to know and learn.

In this context, the necessity emerges for studies that guide teacher training programs based on the knowledge of their representations, conceptions, preconceptions and pedagogical ideas. The valorization of the game by teachers, based on the learning and socialization, and the perception that learning with pleasure, does not ensure that they know, effectively, how to proceed, to valorize the game in its origin, respecting the primary characteristics of the game, which is to be a free, unproductive, unpredictable, symbolic, regulated and well-defined action in terms of space and time of realization. Consequently, discourse and practice may be distance, giving rise to the question "is the game really in the classroom?" It is possible that, in the case of our research, the similarity of the answers, especially regarding the importance for learning, is the result of individual and group reflection on their professional experience in the physical education classroom.

#### Limitations of the study

This study has a number of limitations. The research was conducted only with practicing teachers; for future studies, teachers in initial training could be considered. On the other hand, after the Covid-19 pandemic, it would be interesting to observe the teachers' classes, in order to triangulate the discourse with classroom practice.

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#### Conflict of interest

The authors declare that there are no conflicts of interest.

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## The influence of motor skills on the short sprint results

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### Abstract

**Background and Study Aim** The curriculum of physical education in high schools is based on learning motor skills, as well as their development in sports sections, where the 100-meter sprint dominates. The aim of the study was to determine the influence of motor skills on the 100 m running results.

**Material and Methods** The research was conducted on a sample of 80 high school students in Novi Pazar and Kraljevo, aged 16 and 17 years ( $\pm$  6 months). 12 variables were used to assess motor skills, three variables each: explosive power, segmental speed, repetitive power, and flexibility (standing long jump), triple jump, five jumps. For estimating segmental speed: foot tapping, hand tapping, foot tapping on the wall. For the assessment of repetitive power: lifting the torso on the Swedish bench, mixed pull-ups, squats. To assess flexibility: deep bench press, twine, stick twist.

**Results** Results were obtained to confirm that there is a positive influence of motor skills on the 100 m sprint results at the level of ( $p=.000$ ). The results in the 100 m sprints are statistically significantly dependent on the motor skills that manifest segmental speed and explosive power. Variables (standing long jump, foot tapping on the wall and foot tapping) have a statistically significant effect on the criterion variable of the 100 m sprint.

**Conclusions:** Recommendation to future researchers would be to conduct a study over a longer period of time with the aim of examining the biomechanical factors that determine the success in sprint, is the production of force in the phase of sprint acceleration and sprint deceleration.

**Keywords:** students, teaching, athletics, explosive strength, speed

### Introduction

Physical education classes in secondary schools are based on learning motor skills [1, 2]. As physical education is inadequately represented by the weekly number of hours (two hours), teaching is realized with a low energy component, which is a big problem in achieving the goal and tasks of teaching physical education. Due to such insufficient efficiency of physical education classes, a larger number of children are included in additional exercises within the school section for physical education or in training work in sports organizations. In order to improve the teaching process in secondary schools, research that determines the impact of anthropological status on the specific motor abilities of secondary school students is of scientific interest. Motor skills as the most important factor of anthropological status in the teaching of physical education are mainly related to the influence and relations with other segments: motor, morphological, functional, etc. The importance of anthropology and morphology in attaining better motor fitness including

sprint and the use of motor tests to enhance performance is well documented [3, 4]. One of such segments is the short sprint, which is the subject of research in this article.

Numerous studies showed to a positive relationship between motor skills, and short sprint results [6, 9]. Recent research also indicates that short sprints are a success factor in a number of sports [10, 14]. The most important factors for achieving high results of short sprints are good technique, speed of alternative movements, explosive power as well as maximum force of tried movements [5]. Given the high rate of innate speed (90-95%) training can have very little effect on its development [15, 16]. Studies have also established a predictive association between motor skills and sprints in statistical terms [17]. However, this does not mean that the development of speed should not be influenced, especially in terms of its complex manifestation, but it should be realistic in expectations. Therefore, speed training is mainly focused on the development of reaction speed, the speed of performing one movement and the speed of alternative (frequency) movements. For the development of specific speed, the intensity of technical-tactical exercises is maximum. The pause between repetitions in one series is 1-3s (for

reaction speed and speed of one movement) or none at all (for movement frequency). The number of repetitions in one series depends on the task being performed and the preparedness of an athlete, usually (10-15), while the amount of series per task is (3-5). The pauses between series should be long enough to ensure that the performance speed will be at the level of the previous one [5]. It should be noted that the application of different training methods (for example, plyometric training, resistance training) in a long period of time has a positive effect on the development of short sprints [18, 19].

At the beginning of a sprint run, the ability to generate high concentric force and generate high speed during acceleration is of primary importance for success in short sprints. Shen [20] showed that a 100 m sprint can be divided into 3 different phases: acceleration, maximum speed and deceleration. The acceleration phase can be divided into several sub-phases: initial or initial acceleration (0-12 m), which is mainly characterized by a constant increase in stride length and main acceleration (12-35 m). When the acceleration phase is of sufficient length and the optimal value of the driving speed, the sprinter is not able to maintain the maximum speed and a long deceleration phase occurs [20]. Professional sprinters reach a maximum speed between (50-70 m), and are capable of crossing another (20 m), or rarely (30 m) [21]. Thus, the third transition sub-phase (35-60 m) takes place only at the elite level and lasts until the sprinter reaches the level of maximum running speed. At this stage, the sprinter reaches the maximum stride length, stride frequency and maximum speed. The deceleration was marked only by the last (10 m) of the 100 m sprint [22]. *The aim of the study* was to determine the influence of motor skills on the 100 m running results.

## Material and Methods

### Participants

The research was conducted on a sample of 80 high school students in Novi Pazar and Kraljevo, aged 16 and 17 ( $\pm 6$  months). All participants conducted their activity in regular physical education classes and with three hours a week training process as selected athletes as part of additional classes. The subjects included in the research were healthy and without any chronic diseases, heart problems, is without injuries of the locomotor system that would affect the test results.

### Research Design

A total of 12 tests were used to assess motor skills, three tests each: explosive power, segmental speed, repetition power and flexibility [23]. For the assessment of explosive power: standing long jump (MSDM), triple jump (MTRS), five jumps (MPTS). For estimating segmental speed: foot tapping (MTAN), hand tapping (MTAR), foot tapping on the wall (MTAZ). For the assessment of repetitive power: lifting the torso on the Swedish bench (MDTK), mixed pull-ups (MMZG), squats (MČUČ). To assess flexibility: deep bench press (MDPK), twine (MŠPA), stick twist (MISP). A 100 m sprint was used to evaluate the results of running speed [24].

### Statistical Analysis

The data obtained by the previously described procedure were processed by the SPSS 17 statistical program (Statistical Package for Social Science, v17.0, SPSS Inc., Chicago, IL, USA). Basic descriptive parameters were used for data processing: arithmetic mean (Mean), minimum value (Min), maximum value (Max), standard deviation (SD), asymmetry measures (Skewness and Kurtosis).

Regression analysis in this study was used to determine the influence of motor skills (predictor system), on the 100 m sprint results (criterion system). Relevant parameters were calculated for regression analysis: correlation coefficient (R); partial correlation coefficient (Part-R); standardized partial regression coefficient (Beta); multiple correlation coefficient (R); coefficient of determination ( $R^2$ ); value F - ratio (F); level of significance (p); The significance level was set at  $p < 0.05$ .

## Results

The results found in the Table 1 in the subjects in the area of motor abilities of the subjects show that in none of the tests there are significant deviations of the results from the normal distribution. There are at least five standard deviations (SD) in the intervals of minimum (Min) and maximum (Max) results, which indicates a significant dispersion, i.e., sensitivity of motor tests. The values of Skewness show that there are no significant deviations of the results from the normal distribution in any of the measures, considering that the values do not exceed 1.00 in any of the tests. The Kurtosis values in all tests are below 2.75, which indicates platykurtic distribution.

The obtained results of motor skills do not deviate from the results of similar researches verified in our country on this population of examinees, and thus the application of multivariate methods of processing the results in this research is enabled.

The results determined in the Table 2 in the subjects in the area of sprint running of the subjects show that there are no significant deviations of the results from the normal distribution. The values of Skewness show that there are no significant deviations of the results from the normal distribution, considering that the value does not exceed 1.00. The Kurtosis values in all tests are below 2.75, which indicates platykurtic distribution. The obtained results of sprint running do not deviate from the results of similar researches verified in our country on this population of examinees, and thus the application of multivariate methods of processing the results in this research is enabled. Generalization of the results on the population from which the sample of these participants was derived is thus possible.

Based on the value of the multiple correlation coefficient ( $R=0.81$ ) in the Table 3, it can be stated that motor skills (as a predictor system), based on the size of the coefficient F ratio (5.18) and its significance ( $p=0.000$ ), explain statistically significantly achieved in the short sprint results (TR 100). The coefficient of determination of the criterion variable ( $R^2$ ) and the system of motor

**Table 1.** Basic statistical parameters for the assessment of motor skills

Variables	N	Mean	Min	Max	SD	Skewness	Kurtosis
MSDM	80	183.21	150.00	255.00	9.17	-0.058	1.310
MTRS	80	446.07	390.00	571.00	9.28	-.599	-0.667
MPTS	80	648.63	562.00	715.00	0.28	0.049	-1.065
MTAN	80	28.49	22.00	39.00	4.16	0.385	0.739
MTAR	80	36.55	29.00	46.00	11.47	-0.526	-0.397
MTAZ	80	24.94	19.00	32.00	15.44	-0.635	0.811
MDTK	80	11.62	8.00	27.00	6.49	-0.142	-0.710
MMZG	80	13.69	9.00	25.00	32.60	0.213	1.765
MČUČ	80	19.79	12.00	38.00	3.43	-.231	1.275
MDPK	80	26.33	17.00	44.00	4.14	0.66	0.175
MŠPA	80	156.06	130.00	191.00	3.84	0.193	0.899
MISP	80	76.49	57.00	100.00	2.02	0.939	2.733

Note: number of participants (N), arithmetic mean (Mean), minimum (Min), maximum (Max), standard deviation (SD), standing long jump (MSDM), triple jump (MTRS), five jump (MPTS), foot tapping (MTAN), hand tapping (MTAR), foot tapping on the wall (MTAZ), lifting the torso on the Swedish bench (MDTK), mixed pull-ups (MMZG), squats (MČUČ), deep bench press (MDPK), twine (MŠPA), stick twist (MISP).

**Table 2.** Basic statistical parameters for the assessment of 100 sprints

Variables	N	Mean	Min	Max	SD	Skewness	Kurtosis
TR100	80	12.58	12.46	14.35	11.48	0.314	1.019

Note: number of participants (N), arithmetic mean (Mean), minimum (Min), maximum (Max), standard deviation (SD), 100m sprint (TR100).

**Table 3.** Regression analysis of motor abilities and criteria variables sprint 100 m

R	R <sup>2</sup>	F	p
.81	.64	5.18	.000

Note: multiple correlation coefficient (R), coefficient of determination (R<sup>2</sup>), size of F - relationship (F), level of significance (p)

tests have 64% of common relations. The other 36% of the common variability explain the criterion variables contained in other dimensions of the anthropological space that were not the subject of research in this article.

The results of partial regression (Beta) and its significance (p), at the univariate level, indicate that statistically significant influence on the criterion variable (TR 100), have the following motor variables: standing long jump (MSDM .002), foot tapping on the wall (MTAZ .003) foot tapping (MTAN .005). The following variables also have an influence: hand tapping (MTAR .008), mixed pull-ups (MMZG .008) and squats (MČUČ .009), however, this significance is not at a statistically significant level of (p<0.05). The obtained results of partial regression (Beta) and its significance (p), indicate

that the subjects will achieve better results in the 100 m sprints (TR 100), if they have better motor skills.

### Discussion

The primary aim of the study was to determine the influence of motor skills on the 100 m running results. Results were obtained that show that there is a statistically significant influence of motor skills (predictor variables) on the 100 m sprint results (criterion variables) at the level of (p=.000). Variable for estimating explosive power: standing long jump (MSDM) and segmental speed variables: foot tapping on the wall (MTAZ) and foot tapping (MTAN) have a statistically significant effect on the 100 m running results (TR 100). The variables also have a significant influence: hand tapping (MTAR), mixed

**Table 4.** Statistical significance parameters for the assessment of 100 sprints

Variables	R	Part-R	Beta	p
MSDM	-0.36	-0.12	-4.15	<b>.002</b>
MTRS	-0.16	-0.16	-1.42	.188
MPTS	0.16	0.16	1.50	.210
MTAN	-0.38	-0.35	-3.90	<b>.005</b>
MTAR	-0.31	-0.24	-3.71	.008
MTAZ	-0.28	-0.18	-3.63	<b>.003</b>
MDTK	0.17	0.18	1.44	.155
MMZG	-0.59	-0.50	-3.75	.008
MČUČ	0.51	0.50	3.80	.009
MDPK	-0.11	-0.11	-0.05	.268
MŠPA	-0.15	-0.15	-1.40	.198
MISP	-0.12	-0.12	-1.16	.170

*Note:* correlation coefficient (R), partial correlation coefficient (Part-R), standardized partial regression coefficient (Beta), level of significance (p); standing long jump (MSDM), triple jump (MTRS), five jump (MPTS), foot tapping (MTAN), hand tapping (MTAR), foot tapping on the wall (MTAZ), lifting the torso on the Swedish bench (MDTK), mixed pull-ups (MMZG), squats (MČUČ), deep bench press (MDPK), twine (MŠPA), stick twist (MISP).

pull-ups (MMZG) and squats (MČUČ), however, this significance is not at a statistically significant ( $p < 0.05$ ). Therefore, the obtained results indicate that the success in 100 m short sprints mostly depends on the explosive power and segmental speed.

The results obtained in this way can be said to be expected, because the most important factors for achieving high results of short sprints are the speed of alternative movements, explosive power as well as maximum strength, acquired in squats and strength exercises, is significantly associated with the effect of sprints. The end result of running short sprints depends on the speed of reaction at the start, the ability to show speed in the shortest possible time, as well as on maintaining the maximum speed reached to the finish line [25]. The obtained results can be explained by the fact that in the stage of running at maximum speed on short sprints, the most important structural element of movement is active reflection with the reflecting leg and fast pulling upwards of the swinging leg, previously maximally bent at the knee joint in the phase of the last swing. At the end of the flight phase, the runner performs a downward action with the swinging leg, stretching the leg at the knee and touching the ground with the front part of the foot, and with the reflecting leg, which bends at the same time, it approaches the swinging leg [5]. Also, the high level of explosive power of the lower extremities is positively related to acceleration [26]. Aksović [18] showed that motor skills: speed, power, as well as maximum force of tried movements have a great influence on the results of short sprints in relation to motor abilities: precision, balance, coordination and flexibility, which have less influence in relation to the above motor skills [18]. Mačkala et al. [27] showed a strong correlation between explosive power and

short sprints, indicating that step frequency is the most important factor in the development of maximum speed during the initial and secondary phases of acceleration [27]. Biomechanical factors such as: reaction time, techniques, electromyography (EMG), force production, neuronal factors and muscle structure have a significant role in the short sprint. At the beginning of a sprint run, it is important to produce a lot of force and generate a lot of speed in the acceleration phases. During the constant speed phase, activities immediately before and during the stopping phase are important to increase the explosive force/power and efficiency of movement in the propulsion phase. However, there are no studies that have examined the production of force in the phase of sprint acceleration and sprint deceleration, which is a recommendation for future researchers [28].

### Conclusions

The research was conducted with the aim of determining the influence of motor skills on the 100 m running results. Using regression analysis, the results were obtained to confirm that there is a positive influence of motor skills on the 100 m sprint results at the level of significance ( $p = .000$ ). Variable for estimating explosive power: standing long jump and foot tapping speed variables: foot tapping on the wall and foot tapping have a statistically significant effect on the criterion variable of 100 m running results. It can be concluded that the results in the 100 m sprints are statistically significantly dependent on the motor skills that manifest segmental speed and explosive power. Recommendation to future researchers would be to conduct a study over a longer period of time with the aim of examining the biomechanical factors that determine the success in sprints, i.e., the production of force in the

phase of sprint acceleration and sprint deceleration. The theoretical and practical value of this research is that high school physical education teachers will increase the level of information on the influence of motor skills on the 100 m running results, which will lead to better results in the realization of program tasks of developing abilities and traits and motor skills of students.

### Highlights

- positive influence of motor skills on the 100 m sprint results at the level of significance;

- standing long jump, foot tapping on the wall and foot tapping have a statistically significant effect on the criterion variable of 100 m running results;
- the results in the 100 m sprints are statistically significantly dependent on the motor skills that manifest segmental speed and explosive power.

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### Conflicts of interest

All authors have no conflicts of interest.

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# Improving the means and methods of training of young fencers aged 9-11 years

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## Abstract

**Background and Study Aim** Training of motor actions of young athletes requires consideration the peculiarities of the sensitive period of their development. An important component of the training program is the use of training tools that do not harm the health of young athletes. The purpose of the study is to identify the dynamics of physical training and provide an assessment of technical and tactical techniques of fencers (sword) aged 9-11 years under the influence of the author's program.

**Material and Methods** The study involved young fencers (n = 20; age 9-11 years). The study lasted one academic year. The training was held in the gym of the children's and youth sports school "Wave" (Kharkiv, Ukraine). Athletes were divided into two uniform groups: control group (n = 10) and experimental group (n = 10). Classes were held according to the author's program 4 times a week for 2 hours. A survey of trainers of trainers (n = 12) and experienced fencers (n = 30) was conducted. Parents of children agreed to participate in the study. The following tests were used: "Standing Long Jump Test (Broad Jump), cm"; "4x9 m Shuttle test, sec."; "Hits into the target, 30 sec. points"; "Simulation exercises of a simple fencing combination, sec.". The program "Microsoft Excel" Data Analysis, SPSS was used. The level of reliability is selected p < 0.05.

**Results** Significant changes in the indicators of the control group were obtained: "Standing Long Jump Test (Broad Jump), cm", (p < 0.05); in the test "4x9 m Shuttle test, sec." (p < 0.05); both tests have assessment of technical and tactical techniques (p < 0.01). In the experimental group, all tests showed positive changes (p < 0.01). In comparison of two groups with each other in the tests "Standing Long Jump Test (Broad Jump), cm", "4x9 m Shuttle test, sec." and " Hits into the target, 30 sec. points" there were positive statistically significant changes (p < 0.05). In the test "Simulation exercises of a simple fencing combination, sec." no significant changes occurred (p < 0.05).

**Conclusions:** It is recommended to take into account the effects of exercise on the health of young athletes when designing a fencing training program.

**Keywords:** fencing, physical qualities, physical fitness, health.

## Introduction

The training of young athletes aims to achieve sports results. However, training programs do not always take into account the impact of exercise on the health of young athletes. In the pursuit of results coaches sometimes neglect the health component in building the training process. Therefore, it makes sense to consider the positions of various specialists in fencing on this issue.

Earlier studies have proposed a special set of fencing exercises to expand the arsenal of fighting, as well as the behavior of athletes in unexpected situations [1]. The authors note the need to motivate athletes. This approach should be in the training programs of young athletes.

Building a safe training process takes into account the various components of training. Among them is the formation of young athletes' negative attitudes towards doping. Also, indicate the health consequences of such athletes' behavior. In a study by Poppel et al. [2] it is noted

that coaches play a significant role in the attitude of young fencers (swords) to their own health. The authors offer their own views on the role of the coach in the prevention of doping by young athletes. In this aspect, Mroczkowska [3] believes – "The assessment of objective risk depends more on the rank of what may be lost (health) than on what may be gained (medals)." The author analyzes the possible losses in the use of doping by young athletes. Among such losses is the risk of declining health of young athletes in the early stages of training [3]. An equally important component of the health of young athletes is the compliance of loads with the initial periods of training. In this context, the health component should be present in training programs.

Another area of design training programs for young fencers is the methodological basis for the development of motor skills. Movshovich et al. [4] reveal the methodological foundations for the development of coordination skills of young fencers. The authors believe that the main principle of technical development in the training process of young athletes should be considered

mastering the performance of fencing movements with maximum variability, rather than maximum speed.

Specialized training of young athletes has its risks. Among them are the risks of injury due to overload. This is confirmed in studies of different orientations [5, 6]. In general, the authors agree that excessive workload is the result of poor construction of the training program. The authors believe that aerobic exercise is more appropriate in the early stages of training young athletes.

It is known that a complex combination of a large amount of training and academic requirements can hinder the cognitive and academic results of young athletes. Granacher et al. [7] believe that the complex combination of a large amount of training and academic requirements can hinder the cognitive and academic performance of young athletes. The authors offer a program of school 1-year sports training in combination with physical education. The use of such a program improved physical fitness, but did not negatively affect the cognitive and educational performance of young athletes.

Malina et al. [8] investigated the relationship between invasive and non-invasive indicators of biological maturation in young athletes. The authors propose to include in the skills development programs the classification of young people into early, middle and late maturity status. This will improve the quality of training programs and competitions. Detanico et al. [9] consider it necessary to take into account indicators of somatic maturation, growth and training experience in training programs for young athletes.

Another study proposes to include a combination of game training and high-intensity interval training in the training program [10]. Sharma et al. [11] consider it necessary to conduct cardiac screening before the participation of young athletes in sports competitions. Such screening should be voluntary, not mandatory, and performed by experienced physicians.

Gaining fencing experience is impossible without the development of physical qualities, as well as mastering the technical and tactical techniques of fencing. The means and methods of the educational and training process must be constantly improved and correspond to modern trends in the development of the sport. This should be the basis for acquiring and improving the level of fencing skills [12-14].

The purpose of the study: to investigate the dynamics of physical training and provide an assessment of technical and tactical techniques of fencers aged 9-11 years under the influence of the author's program.

## Material and Methods

### *Participants.*

Under observation were fencers (n = 20; age 9-11 years) of the basic training group, who train in the gym of the children's and youth sports school "Wave" (Kharkov, Ukraine). Athletes were divided into two uniform groups: control group (CG; n = 10) and experimental group (EG; n = 10). Classes were held 4 times a week for 2 hours. In EG classes were conducted according to the author's

program. A survey of coaches and experienced athletes was conducted (n = 42). The children's parents agreed to participate in the study. This study was approved by the Bioethics Committee for Clinical Research and conducted according to the Declaration of Helsinki.

### *Research design.*

The study lasted one academic year. A survey of coaches and experienced athletes was organized. The purpose of the questionnaire is to identify the main areas of overcoming shortcomings in the training of young fencers.

The control group was engaged in the standard program for children and youth sports school fencing department (4 times a week for 2 hours) [15]. The experimental group worked on the author's program 4 times a week for 2 hours. The content of the author's program differed from the standard set of special exercises.

The author's program consists of special jumping exercises; exercises with sports tires; mobile games with fencing equipment; sets of exercises and maneuvers in the battlefield; special exercises on the target.

Assessment of physical fitness of young fencers was carried out according to the following standard tests: "Standing Long Jump Test (Broad Jump), cm"; "4x9 m Shuttle test, sec." [16]. Testing was conducted at the beginning of the experiment. Retesting was conducted at the end of the experiment.

Evaluation of the implementation of technical and tactical techniques was carried out according to such tests as:

- 1) "Hit into the target, 30 sec. points" (Fig. 1):
  - used a target that is equipped with 5 marks of different diameters (the smallest - 25 points, the largest - 5 points);
  - starting position of the athlete - short distance;
  - hits are performed on the target. The result is the number of points scored in 30 seconds. The attempt is not credited if the participant has never hit the mark on the target within 15 seconds.
- 2) "Simulation exercises of simple combination, sec." (Fig. 2):
  - steps: forward-jump; forward- lunge;
  - steps back- lunge;
  - leap forward- lunge;
  - backwards-fleche attack.

The athlete gets on a guard position, puts leg (front leg) on the line. On command, the athlete performs:

- 1- steps forward: as soon as the leg (front leg) crosses the line, the athlete performs a leap forward- lunge;
- 2- steps back: as soon as the leg (front leg) crosses the line, the athlete performs a lunge;
- 3- jumps forward: as soon as the leg (front leg) crosses the line, the athlete performs backwards-fleche attack;
- 4- jumps back: as soon as the leg (front leg) crosses the line, the athlete performs a fleche-attack.

The result is runtime of one combination. An attempt can not be counted if the athlete performed the attack before crossing the line.

- 3) "Complex reaction with a choice, sec." (Fig. 3)

The athlete gets on a guard position. The cones are



**Figure 1.** Test “Hits into the target, 30 sec. points” (photo - Irina Kriventsova)



**Figure 2.** Test “Simulation exercises of simple combination, sec.” (photo - Irina Kriventsova)



**Figure 3.** Test “Complex reaction with a choice, sec.”

placed in front, behind, to the right and to the left at a distance of 2 meters on all sides of the participant. Depending on the placement (side) of the cone (front, back, left, right), the corresponding option of moving to it is performed: in front – steps forward; behind – jumping forward; on the left – steps back; on the right – jumping back. The coach step by step naming the parties freely.

The athlete must react as quickly as possible: perform the appropriate movement option and go beyond the line of a certain cone. If the direction of the athlete’s starting position does not coincide with the direction of movement, he/she must jump to take the correct starting position. The result is the average latency reaction time (the time from the moment when a certain side was named

to the beginning of the participant's movement) for 3 attempts. Remarks: the participant must keep the guard position when moving; legs should not be straightened while performing movements. An attempt can not be counted if the participant has incorrectly completed the appropriate movement option.

*Statistical analysis.* The program "Microsoft Excel" Data Analysis, SPSS was used. It was determined the following indicators: standard deviation, the reliability of the differences between the parameters of the initial and final results and between CG and EG (Student's t-test). The level of reliability is selected  $p < 0.05$ .

## Results

According to the results of the survey of coaches and experienced athletes, it was found that the main areas of overcoming shortcomings in the training of fencers are:

- inclusion in the training process of strength training, stretching, jumping exercises, exercises on special devices, exercises to prevent typical injuries;
- improvement of material and technical support of the sport, assistance of the state and/or sponsors in financing the participation of athletes in ranking competitions;
- involvement of assistant coaches in providing individual lessons in fitness and other types of physical training, rehabilitation, psychological training; the use of video reviews of the training of leading fencers, the use of modern devices for determining physiological parameters [17].

The dynamics of the level of general physical fitness under the influence of the developed program indicates significant changes in indicators (Table 1). In CG: "Standing Long Jump Test (Broad Jump), cm" ( $t = 0.014$ ,  $p < 0.05$ ); "4x9 m Shuttle test, sec." ( $t = 0.021$ ,  $p < 0.05$ ); in both tests of assessment of technical and tactical techniques ( $p < 0.01$ ).

In comparison of two groups with each other in the tests "Standing Long Jump Test (Broad Jump), cm", "4x9

m Shuttle test, sec." and "Hit into the target, 30 sec. points" there were positive statistically significant changes ( $p < 0.05$ ) (Table 1). In the test "Simulation exercises of a simple combination, sec." and "Complex reaction with a choice, sec." no significant changes occurred ( $p > 0.05$ ), although there is a noticeable trend of improving the results in EG. It is possible that one year is not a sufficient period for the reliable formation of these indicators. It takes more time.

As can be seen from Table 1, the reduction of the standard deviation in the groups occurred in the tests "4x9 m Shuttle test, sec." and "Simulation exercises of simple combination, sec.". This indicates a gradual alignment between stronger and weaker athletes in the groups.

Results of "Standing Long Jump Test (Broad Jump), cm" and "Hit into the target, 30 sec. points" show the increase in standard deviation. This indicates a greater discrepancy between the representatives of the group against the background of a slight and significant improvement in test results. The same tendency is observed at mastering of technique of performance of difficult exercises by separate athletes of groups.

## Discussion

The study confirms the opinion of many experts in the field of physical culture and sports about the importance of health-oriented training of young athletes. McGuine et al. [18] note that health policy experts should take health indicators into account when designing and implementing policies to improve adolescent health. Baumgartner et al. [19] believe that moderate physical activity in young athletes is associated with a reduced risk of cardiovascular disease. Other studies [20-24] also emphasize the need to care for the health of children and young athletes in physical activity at various levels. The authors also note the role of parents / coaches and the benefits of gender-sensitive physical activity programming. Our program also takes into account such an important component as the health of young athletes.

**Table 1.** Comparison of the dynamics of indicators of physical training under the influence of the program in CG and EG

Test	The beginning of the experiment				The end of the experiment			
	$X \pm \sigma$		t	p	$X \pm \sigma$		t	p
	CG (n=10)	EG (n=10)			CG (n=10)	EG (n=10)		
Standing Long Jump Test (Broad Jump), cm	163.2±10.6	164.7±6.7	0.32	>0.1	164.7±12.47	172.7±10.07	0.02	<0.05
4x9 m Shuttle test, sec.	11.8±0.44	11.94±0.51	0.27	>0.1	11.64±0.42	11.2±0.42	0.024	<0.05
Hit into the target, 30 sec. points	474.5±131.5	547±82	0.12	>0.05	493.5±136.5	618.5±93.5	0.04	<0.05
Simulation exercises of simple combination, sec.	12.43±1.45	12.91±1.36	0.17	>0.05	12.08±1.08	11.7±1.05	0.29	>0.05
Complex reaction with a choice, sec.	1.698±0.24	1.69±0.22	0.49	>0.05	1.627±0.19	1.503±0.13	0.15	>0.05

We agree with the conclusions of other authors that the development of tactical thinking is based on the ability to monitor closely, quickly analyze and make the right decision [1, 25]. The authors note that the development and improvement of tactical skills has individual and long-term acquisition of relevant skills.

Our program was designed taking into account the need to diversify the techniques of fencers and adhere to the quality of their performance. Techniques during the fight acquire tactical meaning and become fighting operations. It is the expansion of the arsenal of hostilities that favors the fencer.

Harrison CB et al. [10] note that the combination of game and high-intensity interval training provides positive changes in the training of athletes. We believe that game and competitive methods are leading in the training of young athletes. That is why we have developed and adapted 8 games using fencing equipment.

Palmer-Keenan and Bair [26] note that the competitive method is a factor that can confuse competitors. We do not fully agree with this statement. In such cases, it all depends on the proper planning of exercise, which should be available to participants. In this context, our program takes into account the pedagogical principles of accessibility and adequacy of the level of physical activity of young athletes.

We agree with the opinion of other authors [4, 27, 28] that mastering the performance of fencing movements should be performed with maximum variability. However, it should be noted that when performing technical techniques, it is necessary to apply a gradual transition from the minimum rate of execution to the maximum and return to the minimum. In this case, the athlete should try to adhere to the preservation of exercise techniques.

Chtara et al. [27] note that the use of the test of change of direction for fencers is closely related to the selected indicators of physical fitness. In this context, we can say that such tests were used in our program. These tests were

developed and tested by us with the participation of young athletes and they differed slightly from the standard ones offered by the program for sports schools.

An important element of our program is the special attention to the implementation of fleche technique. This attack is also analyzed in the study of Fatemeh [29]. The author presents estimates of biomechanical indicators of fencing athletes according to the criteria of ankle injury during landing after fleche technique. It is stated that professionals should pay attention to the balance of muscle strength before tournaments. We fully agree with this statement. However, it should be noted that the correct technique of performing a complex fleche attack should be gradually formed in young fencers under the careful control of the coach.

Our results prove that under the influence of the author's program there were positive changes in the indicators of all selected tests. Tests on general physical fitness and hits into the target are reliable ( $p < 0.05$ ). And tests on the implementation of simulation exercises and the composition of the reaction of choice have a tendency to improve. This indicates a long-term acquisition of relevant skills.

### Conclusions

The author's program was aimed at diversifying the educational and training process at the stage of initial specialization. The program is based on the expansion of jumping exercises, complex coordination exercises, exercises for stretching muscles, methods of manoeuvring in the fighting stance, exercises on the target.

It is recommended that the effects of exercise on the health of young athletes be taken into account when designing a fencing training program.

### Conflict of interest

The authors report no conflict of interest.

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