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# The impact of combination of core stabilization exercise and walking on pain perception and low-back pain disability

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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** Low-back pain (LBP) has increasingly been the leading cause affecting work performance, daily activities, and rising the cost of healthcare services. Currently, sitting time increases and walking activity lessens among people. The purpose of this study - identify the effect of Core Stabilization Exercise (CSE) with walking on pain perception and LBP disability among people who suffered from non-specific low-back pain (NSLBP).

**Material and Methods** In this study, a total of 36 active people (18-42 years old) with BMI $\geq$ 24.9 kg.m<sup>-2</sup> voluntarily participated and were divided randomly into three groups. Intervention groups included CSE group (CSEG; n=12), CSE with walking (CSEWG; n=12), and control group (CG; n=12). The intervention groups carried out the exercise programs (CSE with and without 30 minutes of walking), three times a week for six weeks. In this study, the pain perception was assessed via the Numerical Pain Rating Scale (NPRS) and LBP disability was measured by using a modified Oswestry Disability (ODI) questionnaire.

**Results** A one-way analysis of variance (ANOVA) displayed significant effectiveness of CSEG and CSEWG on pain perception as the interaction between time and group [f (2, 33) = 4.95, p=0.032]. The pain perception significantly decreased in CSEG (p=0.021) and CSEWG (p=0.003) after six weeks of the intervention programs compare to CG. The results also showed a significant effect on LBP disability for the interaction between time and group after six weeks of both intervention programs (f (2, 33) =6.52, p=0.015). Disability function (ODI score) significantly improved in CSEG (p=0.031) and CSEWG (p=0.007). Even though the results revealed no significant difference between CSEG and CSEWG, and both groups proved to reduce pain perception and LBP disability, the disability index improvement was greatest in CSEWG.

**Conclusions** In conclusion, CSE with 30 minutes of walking, as an intervention program, has shown greater improvement with a larger effect size in pain perception and LBP disability among people who suffered from NSLBP.

**Keywords:** core stabilization exercise, walking, low-back pain disability, pain perception.

## Introduction

It is well-documented that more than 80% of working adults tolerate an episode of low-back pain (LBP) during a period of their lifetime. LBP will increase not only the cost of health care but decreases the working hours and the productivity of the societies [1, 2]. In addition, for many years, LBP has been the leading indication for medical rehabilitation [3] and affected the quality of life as well (4). Furthermore, while previous studies showed that healthcare services for chronic non-specific low-back pain (NSLBP) have considerably

augmented over the past two decades [5, 6], the COVID-19 pandemic now threatens to further intensify the effect of musculoskeletal disease and chronic LBP in many populations [7, 8].

Meanwhile, several curative strategies recently endorse exercise therapy as a first-line treatment for the reduction of musculoskeletal pain and disability improvement. The exercise can improve back extension strength, mobility, endurance, and functional disability [9, 10]. Thus, people who suffer from NSLBP need to do exercises that help to recover their pain and disability in daily life. Besides, there are various types of land-based and water-based exercises for NSLBP such as lumbar stabilization exercise (LSE), lumbar flexion exercise, motor control

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exercise, core exercise, lumbar flexion exercise, bracing exercise, walking exercise (WE), and also aquatic exercise as a non-weight bearing workout that helps in the treatment and rehabilitation of NSLBP [11, 12]. Next, core stabilization exercise or home-based exercise is the type of exercise that is considered a standard and effective physiotherapy intervention which people with NSLBP may follow. Furthermore, flexibility and core strength (e.g., stretching and strengthening exercises) not only can improve the quality of life but also can help to avoid worsening LBP, particularly NSLBP [13, 14, 15]. Besides, core strength home-based exercise has shown a long-term effect for up to one year [16]. In addition, walking is not only a favorable, convenient, easy, and inexpensive exercise for all populations [17], but recently it is also highly recommended to rehabilitate patients with NSLBP [12].

On the other hand, recent studies revealed that walking activities decline among people who suffer from NSLBP [11, 18], while low-moderate evidence revealed the benefit of walking as an effective intervention strategy for LBP treatment [19, 20]. Hence, this study has been carried out to determine the effect of a six-week CSE with walking exercise (CSEW) on pain perception and LBP disability for individuals who suffer from NSLBP.

## Materials and Methods

### *Participants*

This study was a randomized control trial (RCT) with the intervention programs among equivalent groups. The participants were active people who suffered from NSLBP. All participants were informed of the study procedure and signed a consent form before participation. This study was approved by Sultan Idris Education University Ethical Committee.

A total of 41 participants (male and female) who reported LBP in Sultan Idris Education University (UPSI) Sports Rehabilitation Clinic were recruited. Finally, 36 of them completed the study procedure. The inclusion criteria for acceptance were aged 18-45 years, physically active lifestyle, suffering from NSLBP for more than six months with at least two symptoms of LBP. The considered symptoms were overall pain report, difficulty and feeling more pain intensity when lifting, prolonged sitting (>30 minutes), changing postural position, and poor sleep quality. The exclusion criteria included surgery, cardiorespiratory health problems, feeling any uncomfortable or dizziness during walking, feeling pain in any part of the body during exercises, and not attending two consecutive sessions in a week.

The subjects were randomly divided into three groups; the core stabilization exercise group (CSEG), CSE with walking exercise (CSEWG) as intervention groups, and the control group (CG). Each group consisted of 12 active people with NSLBP. The CSE

group conducted only the CSE program and, CSEW also performed CSE after 30 minutes of walking exercise for six weeks, three sessions weekly. Meanwhile, the control group did not do any exercise or intervention program during these weeks.

### *Sample Size.*

A total sample size of 36 (n=12 per group) was recommended by G\*Power 3.0.10 when assuming a size of 36, a power of 0.95 %, and a type I error of 5% for three groups with 10 numbers of predictors (sub-sections of ODI).

### *Research Design*

#### *Instrumentation.*

In this study, the Numeric Rating Pain Scale (NRPS) was used as a research instrument to measure pain perception [21]. The modified Oswestry disability (ODI) questionnaire (Bilingual; English-Malaysian Malay) was also accomplished to measure NSLBP disability. The measurement procedure was completed by all participants one day before (Baseline data) and a day after the intervention program as the post-test.

ODI questionnaire is subtended by 10 sections including pain intensity, personal care, lifting, walking, sitting, standing, sleeping, social life, traveling, and employment/homemaking [11, 22]. Each section was separately scored (0 to 5 points) and then amounted up (total=50). As a participant completed all 10 sections, it would indeed double the patient's score (maximum total=100). Additionally, the data of weight, height, and BMI were self-reported measurements. It should be mentioned that to ensure their health background, all of the participants completed the General Health Questionnaire (GHQ), Physical Activity Readiness Questionnaire (PAR-Q), and an informed consent form as well.

#### *Core Stabilization Exercise with Walking.*

A six-week core stabilization exercise (CSE) with and without walking was conducted three sessions weekly for 60 minutes per session as the intervention program [23, 24]. The first session of the CSE program was carried out in UPSI Sports Rehabilitation Clinic and all of the participants in both intervention groups were taught how to perform the CSE in proper posture and method. Other sessions of CSEG are performed at home while they are motivated and supported via communication and advisory session at least once a week. Meanwhile, CSEWG performed CSE in an outdoor environment after walking for 30 minutes on a flat pathway. They were advised to walk comfortably at their preferred walking speed. As table 1. shows, stabilization and strengthening exercises were performed as part of the CSE program. The exercises were concentrated on the abdominal muscles including trunk rotations, partial crunches, knee to chest, bridging, hip extension, extended

pose, and hand-knee rocking [13, 23]. Moreover, 10 minutes warm-up activity and as well as cool-down activity (5-7 minutes) were considered at the end

of each session. The exercise, repetition, set, and resting time between each exercise based on the week and session are shown in Table 1, also.

**Table 1.** A summary of six weeks of Core Stabilization Exercise (CSE)

Week	Exercise	Session	Self-chosen Rep. & Set	Hold & rest time (Sec)
1	Trunk rotations*	1	5-8 × 2	30
	Partial crunches			*30
	Knee to chest*	2	6-8 × 3	40
	Bridging			*40
	Hip Extension	3	8-10 × 3	60
	Extended pose			60
2	Trunk rotations*	1	6-8 × 4	*30
	Partial crunches			60
	Knee to chest*	2	6-8 × 4	*30
	Bridging			60
	Hip Extension	3	8-10 × 3	*30
	Extended pose			60
3	Trunk rotations*	1	8-10 × 4	*30
	Partial crunches			60
	Knee to chest*	2	10-12 × 3	*30
	Bridging			60
	Hip Extension	3	10-12 × 3	*30
	Extended pose			60
4	Trunk rotations*	1	10-12 × 4	*60
	Partial crunches			80
	Knee to chest*	2	12-15 × 3	*60
	Bridging			80
	Hip Extension*	3	10-12 × 4	*60
	Hand-knee rocking			80
5	Trunk rotations*	1	10-12 × 4	*80
	Partial crunches			90
	Knee to chest*	2	10-12 × 4	*80
	Bridging			90
	Hip Extension	3	12-15 × 3	*90
	Extended pose			120
6	Trunk rotations*	1	12-15 × 3	*90
	Partial crunches			120
	Knee to chest*	2	12-15 × 4	*90
	Bridging			120
	Hip Extension	3	12-15 × 4	*90
	Extended pose			120
	Hand-knee rocking			120

### Statistical Analysis

The data were collected as “baseline” (before the intervention program) and “post-test” after session 18 of the CSE and CSEW programs. Subsequently, evaluating the normal distribution of data for all variables, the mean and standard deviation for the demography data, pain perception, and LBP disability function were analyzed using IBM SPSS Statistics “ver. 27.0” (IBM Co., Armonk, NY). For each variable main and interactive effects of group and time were determined by using a one-way analysis of variance (ANOVA) if there was a significant difference between CSEG, CSEWG, and CG. The significant level was considered at  $p \leq 0.05$ , also.

### Results

As the primary examination of demography data displayed, there was no significant difference between CSEG, CSEWG, and CG in their age, weight, height, and BMI. As mentioned earlier, 36 participants in three groups completed the post-test of NRPS and modified ODI questionnaire. The average attendance of CSEG and CSEWG was 97 % during 6 weeks (18 sessions). In CG, 16.7% (two persons) of participants stated that they continued their physiotherapy exercise instruction for 15-20 minutes regularly at home every morning.

It should be declared that although CG participants were advised to have no exercise for six weeks, this study was not able to control all of their self-treatment situations. The demographic data

(gender distribution, NSLBP experiences, weight, and BMI) of each group is illustrated in Table 2.

In addition, the disability index for NSLBP among CSEG and CSEWG before and after six weeks show in Table 3. It is worth remarking that based on the ODI questionnaire score interpretation, individuals with minimal index can cope with most of their daily activities and generally they do not need treatment, except the advice on lifting, prolonged sitting, physical fitness maintenance, and diet. In moderate index, individuals not only feel more pain and have difficulties with lifting, sitting, and standing, but the travel and social life are also more problems and they may be off from their work [11].

Considering the information in Table 3., the frequency of CSEWG in the moderate index considerably changed to minimal after six weeks of the intervention. However, there was an improvement in the frequency of moderate to minimal index for the CSEG, while there were no notable changes among the control group.

One-way ANOVA test was conducted to analyze the effectiveness of CSE and CSEW on pain perception in the interaction between time and group,  $f(2, 33) = 4.95, p = 0.032$ . In addition, the post-hoc analysis found that the time effect was also significant in both intervention groups (CSEG with  $p = 0.021$ ; and CSEWG with  $p = 0.003$ ), which showed the pain perception significantly diminished after six weeks (18 sessions) for both intervention groups.

The LBP disability (ODI score) significantly lessened among CSEG ( $p = 0.031$ ) and CSEWG

**Table 2.** Demographic data of participants by group (Mean±SD)

Group/Variables		CSEG	CSEWG	CG
Gender	M	3 (25)	4 (33)	5 (42)
	F	9 (75)	8 (67)	7 (58)
NSLBP Experience (Year) n (%)	>2	4 (33)	2 (17)	3 (25)
	1-2	5 (42)	6 (50)	6 (50)
	<1	3 (25)	4 (33)	3 (25)
Age (Years)		32.85±7.43	29.2±9.13	34.8±6.25
Height (cm)		163.3±7.2	164.68±5.33	166.8±6.51
Pre-Weight (kg)		63.17±8.31	65.4±9.11	67.3±8.64
Post-Weight		64.43±9.2	64.6±8.46	66.9±9.93
Pre-BMI (kg.m <sup>-2</sup> )		24.78±3.65	24.02±4.79	23.25±4.18
Post-BMI		24.45±4.12	23.81±4.79	23.01±4.92

**Table 3.** Disability index of LBP by the groups and times (n & %)

Disability Index (0-100)	CSEG		CSEWG		CG	
	Baseline	Post-test	Baseline	Post-test	Baseline	Post-test
Minimal (0-20)	5 (41.7)	8 (67)	4 (33)	11 (91.7)	7 (58.4)	6 (50)
Moderate (21-40)	6 (50)	4 (33)	8 (67)	1(8.3)	4 (33.3)	6 (50)
Severe (41-60)	1 (8.3)	-	-	-	1(8.3)	-

**Table 4.** The pain perception and LBP disability before and after the intervention (One-way ANOVA)

Variable/group	Pain Perception; NPRS; (0-10)				LBP disability; ODI Score (0-100)			
	Baseline	Post-test	F	p	Baseline	Post-test	F	p
CSEG (n=12) (n=12)	5.0±2.4	2.3±1.0	5.83	0.021	33.6±6.70	17.02±4.33	5.02	0.031
CSEWG (n=12)	4.5±2.0	1.10±1.0	10.35	0.003	35.4±6.20	8.32±5.4	8.20	0.007
CG (n=12)	4.7±2.7	3.9±2.0	1.08	0.37	32.7±5.70	28.9±6.3	1.46	0.27
F	0.62	4.95	-	-	0.19	0.83	-	-
p	0.56	0.032	-	-	6.52	0.015	-	-

Note: Data presented as mean ± SD.

( $p=0.007$ ) compared to the control group. In other words, the group-by-time interaction effect revealed an improvement in LBP disability after six weeks of both programs ( $f(2, 33) = 6.52, p=0.015$ ). However, the results of the post-hoc analysis showed no significant changes in these variables after six weeks in the control group (Table 4).

### Discussion

Given NSLBP prevalence and its consequence on public health and the socioeconomic, the present study aimed to examine the impact of the implementation of a six-week CSE with a walking program on pain perception and LBP disability among people who suffer from NSLBP. These findings figured out that a combination of the CSE program together with 30 minutes of walking on a flat pathway with a preferred and comfortable speed could reduce the pain perception and enhance LBP disability. Despite, Hendrick et al. [19] study reported that there is a limited effect of walking on the pain management of acute and chronic NSLBP. This study's findings were in line with recent evidence which similarly found that walking can be an effective treatment program on pain relief and muscle endurance improvement among individuals with NSLBP [12].

Further, Heureux et al. [24] revealed that a combination of favorable rehabilitation exercise and extension of the self-efficacy exercise program is needed for individuals who experienced NSLBP. Then, walking can widely be accepted as the energy efficiency of muscular work to incorporate in general self-efficacy exercise [17]. Furthermore, walking can be considered a helpful rehabilitation program to improve back muscles strengthening and lessening muscle stiffness by inducing isometric contractions of the lower body and increasing muscular activation which consequently resulted in the NSLBP prevention [12].

In addition, these findings are consistent with Sitthipornvorakul et al. [20] study that reported walking can be suggested as an easy and highly accessible to perform in chronic LBP management to reduce the pain and disability. Even though

high-quality studies are still needed to provide supplementary evidence [20].

Furthermore, the study by Kapetanovic et al. [23] revealed that core stabilization exercise (CSE) throughout an organized home exercise plan can improve physical function disability among individuals with chronic LBP. Meanwhile, the current study's findings displayed that the combination of CSE and 30 minutes of walking activity had a better consequence on improving pain perception and functional disability index compared to CSEG that only performed CSE as a treatment program.

However, there is not only a significant effect of the correct core strengthening and stabilization in NSLBP prevention [12] but walking can be counselled as one of the effective ways to encourage a higher activation to maintain a proper posture among people with NSLBP [18].

Nevertheless, a walking gait like an inverted pendulum can induce transverse counter-rotation between the thorax and pelvis, particularly when individuals walk with normal velocity and comfortable speed [25]. Therefore, as CSE can improve back extension strength and mobility [18], the combination of walking and CSE can provide excessive endurance, strength, and mobility to improve all sub-sections of LBP disability like personal care, sitting, standing, walking, lifting, and traveling.

Next, according to Trampas et al. [26] findings, CSE has been proposed as an effective treatment to improve spinal stabilities to address chronic NSLBP and impairments of movement coordination for the trunk and thorax [26]. In addition, according to recent studies, walking exercise could amend the endurance of back muscles as well as the core stability [12, 27, 28, 29]. Considering the findings of this study, a combination of CSE and walking exercise can be recommended for people who suffer from NSLBP. Meanwhile, further research with larger sample size, different intensities, and times of walking is required to discover different findings of the packages of core stabilization prescriptions for walking about prevention and rehabilitation of individuals with NSLBP.

## Conclusions

In conclusion, the finding of the present study figured out that people with NSLBP can significantly improve pain perception and low-back pain disability after a six-week (18 sessions) CSE with 30 minutes of walking (preferred speed). Even though the CSE program could enhance pain perception and low-back pain disability, the implementation of walking as an easy, simple, accessible, and pleasurable activity besides core stabilization exercise can be offered as a superior intervention treatment for people who are suffering from NSLBP.

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## Conflict of interest

The authors reported no potential conflict of interest.

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# Changes in body composition and blood parameters in sedentary women during 12 weeks of complex exercises

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## Abstract

**Background and Study Aim** There are studies examining the effects of exercise programs on body and blood parameters in sedentary individuals, but there are few studies examining the effects of resistance and cardio exercises in combination. The aim of this study was to investigate the effects of step-aerobic, cardio and resistance training on body composition and blood parameters in sedentary women for 12 weeks.

**Material and Methods** Step- Aerobic, Cardio and Resistance exercises were applied to the volunteers participating in the study for 12 weeks, 3 days a week for 1 hour each. Body weight, body mass index, body fat percentage and body muscle percentage values were determined from body composition measurements before and after the application. Glucose, Vitamin D3, Triglyceride, Cholesterol, High-density lipoprotein and Low-density values were measured from blood parameters. There is no exercise planning was done in the control group.

**Results** After the exercise program, a significant decrease ( $p < 0.05$ ) in body weight, body mass index, body fat ratio, Glucose, Vitamin D3, Triglyceride, Cholesterol and Low-density values and a significant increase ( $p < 0.05$ ) in High-density lipoprotein and values were determined in the study group. In the control group, no significant change was observed in both body composition and blood parameters ( $p > 0.05$ ).

**Conclusions** In the this study, it was found resistance, cardio and step-aerobic exercise programs had a positive effect on body composition and blood parameters in sedentary women. In the control group, there is no positive data for the end of the this study and there is no significant change not only body parametres bu also blood measurement in the control group.

**Keywords:** exercise, blood parameters, physical fitness, body mass index.

## Introduction

Technological developments facilitate our daily lives and save our time. However, this situation negatively affects human health and increases the incidence of various diseases such as cardiovascular disorders, diabetes, obesity, posture disorders. Obesity is linked to cancer, diabetes and heart diseases [1, 2, 3, 4]. Epidemiologic studies indicate that time spent watching television or sitting increases mortality rates and that a sedentary lifestyle has a positive relationship with the risk of type 2 diabetes [2]. Especially in countries with high income levels, the incidence of conditions such as smoking, excessive alcohol consumption, hypertension is increasing rapidly [3, 4]. People use the words exercise, physical activity and sport as if they are the same practices, but they are not fully aware of the differences in these practices. Physical activity is defined as all movements in which the human organism expends energy regardless of form, space and intensity; exercise and sports practices are generally accepted as sub-dimensions of physical activity [5]. In the US Department of Health reports, it is stated that participation in adopted physical

activity is an indicator of an active lifestyle [6].

In humans, body composition is defined as lean body weight, muscle mass and bone ratio [7]. An exercise prescription built on the correct configuration increases the initial motivation in sedentary individuals and increases the dependence of individuals on the exercise program [8]. It is stated that an exercise program planned in line with this planning causes the muscles to use a large amount of glucose during the activity and the increased sensitivity of the muscles to insulin after exercise, the effect of insulin made after the intensive exercise program is faster and thus blood sugar decreases [9].

Triglyceride is a measurement that is investigated with blood pressure and cholesterol levels to detect cardiovascular risk factors. In the simplest terms, triglyceride is the ratio of fat in the blood. The rate of fat in the blood can vary after a properly planned exercise program [10]. Cholesterol plays an important role in the human body for cell construction and sex hormone production. When cholesterol levels are high in the blood, there is an increase in cardiovascular risk factors [11]. High-density lipoprotein (HDL) is a fat-like substance that collects cholesterol in tissues and allows it to

be excreted. The reasons for the high presence of cholesterol in the blood; It is stated that there are factors such as old age, diabetes, sedentary life, obesity, stress factors, genetic conditions [12]. High HDL may mean that cardiovascular risk factors are low. HDL ratio increases with regular exercise [13]. Low levels of lipoprotein (LDL) in the blood are produced in the liver and transported through the blood. LDL is a parameter that is analyzed to determine people's heart health risk factors. These two measurements provide a high degree of information about the heart health of individuals [14]. In the literature, it is stated that vitamin D3 has a positive effect on being healthy status such as bone health and muscle fibril structure in adult humans. According to specialist vitamin D3 in humans has been shown to positively influence musculoskeletal health, muscle strength increased in older adults [15]. Vitamin d3 is include natural supplement and a lot of humans is using for skin exposure to ultraviolet [16].

Body mass index (BMI) is a method used to estimate people's body weight in relation to their health problems. Obesity is a condition in which people are excessively fat. Cholesterol, triglycerides, insulin levels, high blood pressure, orthopedic disorders and mental problems are considered as risk factors for obesity [17]. According to the World Health Organization, body mass index classification states that those with  $25 \text{ kg/m}^2$  and above are overweight, those with  $25-29.9 \text{ kg/m}^2$  are pre-obese, those with  $30-34.9 \text{ kg/m}^2$  are 1st degree obese, those with  $35-39 \text{ kg/m}^2$  are 2nd degree obese, and those with  $40 \text{ kg/m}^2$  and above are 3rd degree obese [18].

In the literature, there are various studies investigating the effects of exercise programs on body composition and blood parameters [7, 8, 10, 14]. However, the number of studies using 3 different exercise protocols is quite low.

The aim of this study was to investigate the effects of step-aerobic, cardio and resistance exercise programs using three different exercise types on body composition and blood parameters in sedentary women for 12 weeks.

## Materials and Methods

### Participants

Twenty-seven sedentary women participated in the study as volunteers. The volunteers were divided into two groups as study group and control group. The study group consisted of 15 volunteers with a mean age of  $32.2 \pm 7.3$  (years) and 3 volunteers from this group voluntarily left the study. The control group consisted of 12 volunteers with a mean age of  $32.1 \pm 7.2$  years (mean age  $32.1 \pm 7.2$  years) and no exercise program was applied to this group and they were asked to continue their daily routine lives.

### Research Design

The content of the exercise program applied to the experimental group is presented in Table 1. Under the supervision of expert trainers, the study group underwent an exercise program of 70 to 90 minutes for a total of 36 days, 3 days a week for a 12-week period. Exercise practices were planned as 10-15 min warm-up phase, 40-50 min training program, 10-15 min cool-down phase. Resistance exercises were performed with resistance band squats, bend over rows, lunges, triceps extension, reverse crunch, diagonal wood chops movements using yellow theraband (low difficulty level) 1 day a week. Cardio exercises were performed 1 day a week at a pulse rate of 40-60% using elliptical bicycle, normal bicycle and treadmill. Step-aerobic exercise program was applied with an intensity between 60-80%.

### Blood Analyzes and Body Composition Measurements

In our study, the individuals in the experimental and control groups were instructed not to change their daily eating habits during the exercise program (12-week period). Total cholesterol (TC), high density lipoprotein (HDL), low density lipoprotein (LDL), triglyceride (T), glucose (G), vitamin D3 values were evaluated in blood samples taken from all volunteers. In the blood samples taken from the experimental and control groups, 10ml biochemical kits were used and the data obtained were analyzed in the laboratory of Kayseri City Hospital. In addition, body weight, body mass index, body fat

**Table 1.** Exercise program during the 12 weeks resistance, step-aerobic, cardio exercise of the experimental group

Resistance Exercises			Step-Aerobic			Cardio Exercises		
Week	Set	Reps	Week	Day	Intensity.	Week	Day	Intensity.
1	2	8-10	1	1	%60-80	1	1	%40-60
2	2	10	2	1	%60-80	2	1	%40-60
3	2	10	3	1	%60-80	3	1	%40-60
4	3	12	4	1	%60-80	4	1	%40-60
5	3	12	5	1	%60-80	5	1	%40-60
6-12	3	12	6-12	1	%60-80	6-12	1	%40-60

and muscle ratios were taken from the participants before and after exercise using Tanita BC 601 body analyzer.

*Statistical Analysis*

SPSS 24 program was used in the statistical analysis of the research. In order to determine the skewness kurtosis value of the data, the level of (1.5>X>1.5) was determined and it was decided to use parametric test. Paired sample t test was used for significance analysis between measurements. Significance level p<0.01-0.05 was accepted.

**Results**

In our study, the mean age of the experimental group was 32.7±7 (years) and the mean height was 160.5±6 (cm), while the mean age of the control group was 32.1±7.2 (years) and the mean height was 166.3±7.4 (cm).

The body composition findings of the experimental group are given in Table 2. According to Table 2, a significant decrease was found in the BW, BMI and BFR values of the volunteers after the exercise program (p<0.05). No significant difference was observed in BMR values (p>0.05).

Blood measurement findings of the experimental group are given in Table 3. According to Table 3, a significant difference was found in the triglyceride, cholesterol, ldl, values of the volunteers after the exercise program (p<0.05). No significant difference was observed in hdl, vitamin d3, cholesterol values (p>0.05).

Body composition findings of the control group are given in Table 4. According to Table 4, no significant difference was found in the BW, BMI, BFR, BMR values of the control group (p>0.05).

Blood measurement findings of the control group are given in Table 5. According to Table 5, no

**Table 2.** Comprasion of body weight, body mass index, body fat ratio and body muscle ratio measurements of the experimental group (Paired Sample t Test)

Variable	n	Min.	Max.	Mean Std.	t	p
Body Weight <sup>kg</sup> Pre-test	12	58.1	78.2	72.7±5.8	3.029	.011*
Body Weight <sup>kg</sup> Post-test	12	59.1	76.9	71.6±5.2		
Body Mass İndeks <sup>kg/m<sup>2</sup></sup> Pre-test	12	23.6	32.9	28.2±2.8	3.100	.010*
Body Mass İndeks <sup>kg/m<sup>2</sup></sup> Post-test	12	24.0	32.4	27.8±2.8		
Body Fat Ratio% Pre-test	12	16.3	41.6	30.2±9.2	3.447	.005*
Body Fat Ratio% Post -test	12	17.5	40.3	29.2±8.6		
Body Muscle Ratio <sup>kg</sup> Pre-test	12	41.5	52.0	47.9±3.4	1.542	.151
Body Muscle Ratio <sup>kg</sup> Post-test	12	41.6	51.3	47.5±3.3		

Note: \*p <0.05; BW - body weight; BMI -body mass index; BFR – body fat ratio ; BMR – Body Muscle Ratio

**Table 3.** Comprasion of Glucose, Vitamin D3, Triglyceride, Cholesterol, HDL, LDL analysis results of the experimental group (Paired Samle t Test)

Variable	n	Min.	Max.	Mean.Std	t	p
Glucose <sup>mg/ dl</sup> pretest	12	69.0	112.0	87.3±12.3	.925	.375
Glucose <sup>mg/ dl</sup> posttest	12	68.0	106.0	85.8±11.7		
Vitamin d3 <sup>ng/ml</sup> pretest	12	16.8	34.0	24.7±6.2	1.509	.160
Vitamin d3 <sup>ng/ml</sup> posttest	12	17.1	29.0	23.3±4.		
Triglyceride <sup>mg/ dl</sup> pretest	12	53.0	162.0	91.9±38.9	2.461	.032*
Triglyceride <sup>mg/ dl</sup> posttest	12	37.0	148.0	82.3±34.4		
Cholesterol <sup>mg/ dl</sup> pretest	12	147.0	248.0	171.1±27	5.802	.000*
Cholesterol <sup>mg/ dl</sup> posttest	12	139.0	242.0	163±27		
HDL <sup>mg/ dl</sup> pretest	12	35.0	108.0	57.7±19	1.068	.309
HDL <sup>mg/ dl</sup> posttest	12	30.0	101.0	69.8±18.4		
LDL <sup>mg/ dl</sup> pretest	12	44.8	149.3	94.8±29.9	1.637	.030*
LDL <sup>mg/ dl</sup> posttest	12	37.3	155.2	91.1± 31		

Note: \*p <0.05; HDL - high-density lipoprotein; LDL - low-density lipoprotein

**Table 4.** Comprasion of Body Weight, Body Mass Index, Body Fat Ratio and Body Muscle Ratio Measurements of the control group (Paired Samle t Test)

Variable	n	Min.	Max.	Mean Std	t	p
Body Weight <sup>kg</sup> Pre-test	12	69.7	86.4	77.1±5.9	-4.380	.129
Body Weight <sup>kg</sup> Post-test	12	70	87.1	73.3±6.3		
Body Mass İndeks <sup>kg/m<sup>2</sup></sup> Pre-test	12	21.8	32.7	26.9±3.7	1.672	.984
Body Mass İndeks <sup>kg/m<sup>2</sup></sup> Post-test	12	21.5	33.1	27±3.7		
Body Fat Ratio <sup>%</sup> Pre-test	12	19.7	35.7	25.9±6.7	-1.883	.571
Body Fat Ratio <sup>%</sup> Post -test	12	19.5	39.4	26.9±7.2		
Body Muscle Ratio <sup>kg</sup> Pre-test	12	41.8	57.	49.8±5.2	-3.189	.134
Body Muscle Ratio <sup>kg</sup> Post-test	12	44.6	57.2	51.1±4.6		

Note: \*p <0.05; BW - body weight; BMI -body mass index; BFR – body fat ratio ; BMR – body muscle ratio

**Table 5.** Comprasion Glucose, Vitamin D3, Triglyceride, Cholesterol, HDL, LDL analysis results of the control group. (Paired Sample t test)

Variable	n	Min.	Max.	Mean.Std	t	p
Glucose <sup>mg/ dl</sup> pretest	10	66	100	89±.9	-2.112	.581
Glucose <sup>mg/ dl</sup> posttest	10	68	101	89.9±.9		
Vitamin d3 <sup>ng/ml</sup> pretest	10	17.1	24.5	20.3±2.5	-1.144	.311
Vitamin d3 <sup>ng/ml</sup> posttest	10	17.5	24.2	20.6±2.5		
Triglyceride <sup>mg/ dl</sup> pretest	10	55	100	78.1±12.5	-3.681	.117
Triglyceride <sup>mg/ dl</sup> posttest	10	57	98	80.1±10.8		
Cholesterol <sup>mg/ dl</sup> pretest	10	69	167	190.1±30	-1.558	.089
Cholesterol <sup>mg/ dl</sup> posttest	10	76	165.7	190.8±28.4		
HDL <sup>mg/ dl</sup> pretest	10	73.2	139.1	55.2±11.6	-1.146	.093
HDL <sup>mg/ dl</sup> posttest	10	68.7	170.8	61.5±11.4		
LDL <sup>mg/ dl</sup> pretest	10	44.8	100.5	87±18.5	-2.265	.536
LDL <sup>mg/ dl</sup> posttest	10	43.1	100.4	87.7±19.6		

Note: \*p <0.05; HDL - high-density lipoprotein; LDL - low-density lipoprotein

significant difference was found in glucose, vitamin d3, triglyceride, cholesterol, hdl, ldl values (p>0.05).

## Discussion

Optimally performed exercise planning contributes to insulin sensitivity in non-diabetic individuals who are effective in determining blood glucose levels and helps control blood glucose levels in the group with diabetes. The American Diabetes Association emphasizes that a low-level exercise program applied every week is effective in reducing blood glucose levels [19]. Endurance and short-term high intensity exercises reduce blood glucose levels [20]. There are studies with similar and different results in the literature. Mergen Dalyanoğlu et al. [21] reported a significant change (p<0.05) in blood glucose levels after exercise. In the study applied on performance athletes, it was found that the exercise program had a significant effect (p<0.05) on blood

glucose levels [22]. It is seen that there is a no statistical decrease (p>0.05) in blood glucose levels with participation in the applied exercise program.

It is stated that elevated triglyceride levels, which are responsible for maintaining order in the endocrine system, may cause some risk factors. It is stated that the effect of exercise practices on triglyceride levels in the blood varies according to the duration, frequency and protocol of exercise [23]. In our study, it was observed that the triglyceride values of the participants showed a significant decrease in the post-test (p<0.05) (Table 3). In the similar study found a significant (p<0.05) decrease in triglyceride measurements in their study and reached similar results with our current study [4].

Kraus et al. found that there was a significant decrease in triglyceride levels after the exercise program in their study with the participation of sedentary individuals [24]. In the study in which endurance training protocol was applied, it was

found that exercise increased triglyceride levels initially [25]. In a study conducted on elite wrestlers, it was found that there was no change after the exercise program [26]. Şekeroğlu et al. found in their study that acute and programmed exercise in sedentary individuals caused a sudden increase in blood triglyceride level, while there was a decrease at the end of the program [27]. Based on these findings, it is thought that the effect of exercises on blood triglyceride levels may also be effective from aerobic exercises included in the exercise content, the increase in HDL measurements may have an effect on the significant change in this parameter, and dietary habits after starting the exercise program may also be effective in this process.

Cholesterol is an indispensable molecule for humans (for the synthesis of steroids and other important molecules) as well as being necessary for its structural functions [28]. In the present study, a significant decrease ( $p < 0.05$ ) was observed in the averages after the exercise program in the experimental group (Table 3), while no change was observed in the control group (Table 5). Selçuk et al. determined that there was a decrease in total cholesterol level in women as a result of an 8-week exercise program, but this decrease was not significant and a different result was reached from our study [29]. Guskowska [30] found that there was a decrease in favor of the last test in all group measurements participating in the study. Similar findings were found in studies in which cholesterol levels were found to differ after exercise in middle-aged male individuals [31]. In our current study, the exercise program was limited to 12 weeks. It is thought that factors such as the sports history of the individuals in the sample groups in the studies and the year of participation in exercise may be effective in reaching different findings.

The effect of regular exercise on HDL values depends on several factors. These are; the intensity of exercise and the characteristics of the participant [13]. In our study, there is no ( $p < 0.05$ ) significant increase was found in the mean HDL values of the participants (Table 3). No significant change was observed in HDL values in the control group (Table 5). In a similar study, it was found that a 14-week exercise program caused a 6% increase in HDL values [32]. According to the content of the exercise protocol, an increase in HDL values occurs and it is stated that the continuation of these activities has a positive effect [33, 34]. In their study, İri et al. found that there was a significant increase in HDL values at the end of 8 weeks [35].

High levels of LDL cholesterol in the blood are reported to be an indicator of lipids in the blood

and cardiovascular risk factors and the level of 100-130 mg/dl is accepted as the reference range [36]. In this study, it was found that there was a significant decrease ( $p < 0.05$ ) in LDL values after the exercise program in blood measurements in the experimental group (Table 3), while no difference was detected in the control group (Table 5). Mergen Dalyanoğlu et al. reported that although there was a decrease in LDL levels in his study with sedentary women, this decrease did not show statistical significance ( $p > 0.05$ ) and reached a different result from our study [21]. It is seen that the applied exercise program had a positive effect on the HDL and LDL values of the volunteers. No change was observed in the control group. From these findings, it is thought that participation in a regular exercise program has a positive effect on the reduction of risk factors in individuals.

In our study, it was found that there were decreases in the mean Body Weight, Body Mass Index, Body Fat Ratio, Body Muscle Ratio of the participants and this decrease was significant in Body Weight, Body Fat Ratio, Body Mass Index measurements ( $p < 0.05$ ) (Table 2). There are studies in the literature with similar results with the measurements in these parameters. Among these studies, Schneider et al. [37], Burrowes [38] reached similar results in their study.

It is thought that the significant changes in Body Weight, Body Fat Ratio and Body Mass Index values in the experimental group are due to the effect of exercise participation. It is thought that appropriate exercise program and food consumption may contribute to physical fitness in individuals of all age groups and continuity of physical activities may affect these parameters.

## Conclusion

In this study, it was found that there was a significant change in Body Weight, Body Mass Index, Body Muscle Ratio, Low Density Lipoprotein, Triglyceride and Cholesterol values of sedentary women with the combined application of resistance, cardio and step-aerobic exercises ( $p < 0.05$ ). There are studies with similar and different findings in the literature. It is thought that this differentiation may be due to factors such as the protocol of the exercise applied, the change in body weight caused by exercise application, nutritional habits, and drug use.

## Conflict of interests

The authors reported no potential conflict of interest.

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## Perceived barriers to adopting information and communication technology in physical education

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

### Abstract

**Background and Study Aim** The use of Information and Communication Technologies (ICTs) in Physical Education (PE) brings the science of sports to life by combining physical and mental activity. It also helps students focus better on practical and theoretical work. The purpose of this study was to investigate the perceived barriers to adopting ICTs in PE lessons among high school teachers in Malaysia.

**Material and Methods** A total of 112 Physical Education teachers were selected by stratified random sampling to answer an online questionnaire. Cluster analysis was then conducted to classify PE teachers' profiles according to the frequency scores of experiencing challenges in using ICT tools in PE teaching and learning. Discriminant analyses were performed to determine the significant barriers related to technology that differentiate these clusters.

**Results** In conclusion, Cluster analysis identified three well-defined profiles: cluster 1 (excellent degrees in applying ICT to their teaching practices) consists of 44 teachers; cluster 2 (moderate degrees in applying ICT to their teaching practices) consist of 41 teachers; cluster 3 (poor degrees in applying ICT to their teaching practices) consist of 27 teachers. Results revealed seven out of twelve technology-related barriers were significant among these clusters. They are the insufficient number of computers ( $p < 0.001$ ), insufficient number of internet-connected computers ( $p < 0.001$ ), insufficient pedagogical support for teachers ( $p < 0.001$ ), lack of content in the national language ( $p < 0.001$ ), pressure to prepare students for exams and tests ( $p < 0.001$ ), no or unclear benefit to using ICT for teaching ( $p < 0.001$ ) and perception of using ICT in teaching and learning not being a goal in their school ( $p < 0.001$ ).

**Conclusions** Awareness of these barriers has implications for physical education, curriculum design, teacher training, and youth participation in the school environment. The positive opinions and attitudes of PE teachers toward ICTs as educational tools could pave the way for improving their digital literacy. Thus increase their rate of use of these tools if they are provided with the appropriate technical resources and training.

**Keywords:** information, communication, technology, physical education

### Introduction

In the 21<sup>st</sup> century, educators have access to an almost unlimited number of technological tools to enhance student's learning experiences. Technology can be an educational tool used not only to transform learning but also to foster relationships between students and teachers, close gaps in access to information and support resources, and help meet the needs of individualized learners [1]. Much of the educational technology in use today is accessed through a variety of interactive curricula, programs, apps, and assessment tools available to teachers to enrich their learning experiences in the classroom. Despite the changing role of technology in schools and the emphasis on preparing teacher candidates to master technology, many teachers still feel unprepared to use technology effectively in their classrooms [2]. Therefore, schools should

be confident that teacher preparation programs ensure that new teachers are prepared by higher education institutions to use technology wisely [3]. New teachers leaving a preparation program should not be required to receive remedial instruction from their hiring school or district. Although the need for technology training in teacher education is increasingly discussed, a fundamental problem is the variety and diversity of approaches and strategies used to provide candidates with the knowledge, skills, and readiness to engage with technology as an instructional tool.

To understand the challenge of technology adoption in Physical Education (PE), it is first important to consider the barriers present in the adoption process. A wide range of factors influences teachers' intention to adopt the technology. They include accessibility to technology, support, time to learn, beliefs and values toward technology, training, knowledge, confidence, and skills to operate technology [4]. Besides, PE teachers have

cited limited budget and access to appropriate technology as prominent barriers to technology adoption [5]. Researchers continue to explore the complex factors that influence technology adoption and intention to use. Factors such as perceived usefulness and perceived ease of use embedded in the Technology Acceptance Model 3 (TAM3) [6] have been found to be especially important. Several variables within TAM3 including subjective norms, relevance to work, computer self-efficacy, and perceived enjoyment, appear to influence perceived usefulness and ease of use. For teacher education programs that are in various stages of technology adoption, contextual variables such as administrative support, infrastructure, and funding, as well as faculty development, must be considered and a strategic plan must be created for overcoming potential barriers and obstacles [7]. Given the many variables involved in the use, adoption, and acceptance of technology in a professional context, educators and administrators need to recognize that there is no one-size-fits-all solution or strategy for integrating technology. This is especially true for personal and professional development initiatives.

Much is known about the positive impact of ICT on the teaching/learning process at PE [4, 5, 8]. Numerous empirical work has been conducted to explore how these technological tools can be used as a means for effective and creative teaching. Screen-based technologies, such as computers, tablets, and smartphones, are probably one of the first examples that come to mind when talking about ICT and PE. Teacher education is concerned with how to teach a subject using technology in a pedagogically appropriate way and how to develop the knowledge base for designing and implementing technology-enhanced instruction in physical education [9]. Although the use of ICT in PE has increased globally over the past two decades [8], there remains a data gap on how these technological tools are viewed and used by PE teachers in developing countries. Such data can play a critical role in informing policymakers about opportunities for improvement and technological needs in PE. Therefore, this study aims to identify perceived barriers related to the adoption of technology in PE teaching and learning.

## Materials and Methods

### *Participants.*

A total of 112 Physical Education teachers, aged between 25 and 35 years old ( $M \pm SD = 31.9 \pm 3.3$  years) were selected by stratified random sampling to answer questionnaires on the use of technology in teaching and learning. The sample responded to the statements given and chose their answers based on their perceptions.

### *Research Design.*

Quantitative methodology was used in this study

to collect and analyze the data obtained from all the respondents. A questionnaire was self-developed and finalized by the researchers before being distributed to the targeted group of respondents. The questionnaire was designed specifically to address research objectives concerning teachers' perceived barriers to the use of ICT tools in teaching and learning sessions. A self-developed survey questionnaire consisting of two. Section A consists of demographic information of respondents. Meanwhile, Section B comprises 12 items of challenges in using ICT tools in teaching and learning. The questionnaire was based on 5-point Likert Scale ranging from 5 = always, 4 = often, 3 = sometimes, 2 = rarely and 1 = never.

### *Statistical Analysis.*

Cluster analysis (CA) is used to classify PE teachers' profiles according to the frequency scores of experiencing challenges in using ICT tools in PE teaching and learning. CA is a robust method to identify and categorize components or subjects (observations/population) into clusters with a greater homogeneity state within the class and a greater heterogeneity state among classes about a predetermined selection criterion [10]. Ward's technique utilizing Euclidean distances as a degree of resemblance in CA has shown to be very effective

Discriminant analysis is performed to determine the significant barriers related to technology that differentiate three groups (three sampling groups represent excellent, moderate, and low degrees in applying ICT to their teaching practices), which were obtained by Cluster analysis. The DA was put into the raw data using the standard, forward stepwise, and backward stepwise methods [11]. The relative clusters of the PE teachers were treated as dependent variables whereas all the assessed challenges were treated as independent variables.

## Results

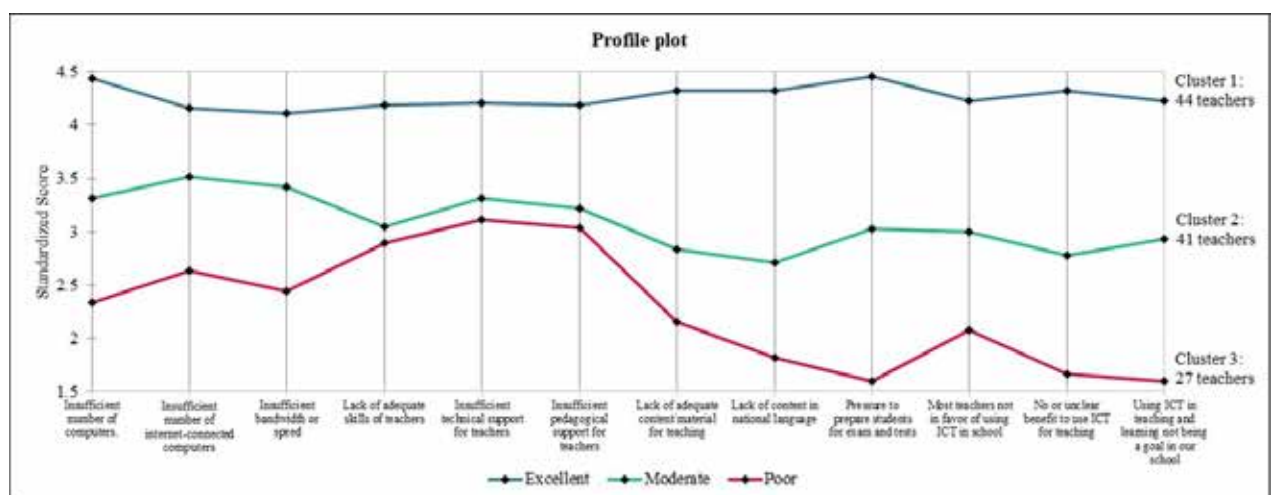
Table 1 shows the frequency of respondents answering questionnaires about challenges in using ICT tools in PE lessons based on their experience at school.

Figure 1 depicts the profile plot of three clusters assigned by Clustering Analysis. A total of 44 PE teachers were assigned to Cluster 1 who experience excellent experience in applying ICT to their teaching practices. This cluster generally agreed they seldom or never experience difficulties when applying technology in their teaching-learning session. Cluster 2 consists of 41 PE teachers who moderately experience difficulties in applying ICT to their teaching practices. Finally, a total of 27 PE teachers were assigned in Cluster 3 who always or often face difficulties in applying ICT to their teaching practices.

Table 2 shows the discriminant analysis

**Table 1.** Challenges in using ICT tools in PE Teaching & Learning

Items	N=112				
	Always	Often	Sometimes	rarely	Never
Insufficient number of computers	0 (0.0%)	24 (21.4%)	33 (29.5%)	28 (25.0%)	27 (24.1%)
Insufficient number of internet-connected computers	0 (0.0%)	16 (14.3%)	41 (36.6%)	32 (28.6%)	23 (20.5%)
Insufficient bandwidth or speed	0 (0.0%)	22 (19.6%)	39 (34.8%)	29 (25.9%)	22 (19.6%)
Lack of adequate skills of teachers	0 (0.0%)	19 (17.0%)	42 (37.5%)	32 (28.6%)	19 (17.0%)
Insufficient technical support for teachers	0 (0.0%)	15 (13.4%)	35 (31.3%)	40 (35.7%)	22 (19.6%)
Insufficient pedagogical support for teachers	0 (0.0%)	16 (14.3%)	34 (30.4%)	46 (41.1%)	16 (14.3%)
Lack of adequate content/material for teaching	6 (5.4%)	26 (23.2%)	35 (31.3%)	24 (21.4%)	21 (18.8%)
Lack of content in the national language	9 (8.0%)	26 (18.8%)	35 (31.3%)	26 (23.2%)	16 (14.3%)
Pressure to prepare students for exams and tests	13 (11.6%)	21 (19.6%)	28 (25.0%)	26 (23.2%)	24 (21.4%)
Most teachers are not in favor of using ICT in school	3 (2.7%)	28 (25.0%)	34 (30.4%)	31 (27.7%)	16 (14.3%)
No or unclear benefit to using ICT for teaching	13 (11.6%)	25 (22.3%)	29 (25.9%)	26 (23.2%)	19 (17.0%)
Using ICT in teaching and learning not being a goal in our school	15 (13.4%)	21 (18.8%)	29 (25.9%)	30 (26.8%)	17 (15.2%)



**Figure 1.** Groups profile plots of different clusters of the relative perceived barriers of the PE teachers

conducted for further analysis. The DA was applied to clusters defined by HACA to look through variation in relative barriers to technology usage. The clusters act as the dependent variable, whereas perceived barriers parameters were treated as independent

variables. Standard, backward stepwise, and forward stepwise mode methods were selected to perform the DA. The precision of classification using standard, backward stepwise, and forward stepwise was 97.32% (12 independent variables), 97.32%

**Table 2.** Classification matrix of Discriminant Analysis (DA) for the relative barrier variations in the three different clusters of PE teachers.

Mode	Clusters	Excellent	Moderate	Poor	Total	% correctness
Standard DA (12 significant barriers)	Excellent	43	1	0	44	97.73%
	Moderate	0	40	1	41	97.56%
	Poor	0	1	26	27	96.30%
	Total	43	42	27	112	97.32%
Forward DA (7 significant barriers)	Excellent	44	0	0	44	100.00%
	Moderate	0	38	3	41	92.68%
	Poor	0	0	27	27	100.00%
Backward DA (7 significant barriers)	Total	44	38	30	112	97.32%
	Excellent	44	0	0	44	100.00%
	Moderate	0	40	1	41	97.56%
	Poor	0	0	27	27	100.00%
	Total	44	40	28	112	99.11%

**Table 3.** Unidimensional test of equality of the means of the classes by Discriminant Analysis Backward (stepwise) mode.

Perceived Barriers to Technology	Lambda	F	DF1	DF2	p-value
Insufficient number of computers	0.413	77.466	2	109	<0.0001
Insufficient number of internet-connected computers	0.629	32.205	2	109	<0.0001
Insufficient bandwidth or speed			2	109	n.s.
Lack of adequate skills of teachers			2	109	n.s.
Insufficient technical support for teachers			2	109	n.s.
Insufficient pedagogical support for teachers	0.682	25.402	2	109	<0.0001
Lack of adequate content/material for teaching			2	109	n.s.
Lack of content in the national language	0.227	185.584	2	109	<0.0001
Pressure to prepare students for exams and tests	0.257	157.733	2	109	<0.0001
Most teachers are not in favor of using ICT in school			2	109	n.s.
No or unclear benefit to using ICT for teaching	0.296	129.508	2	109	<0.0001
Using ICT in teaching and learning not being a goal in our school	0.333	109.381	2	109	<0.0001

n.s. = not significant

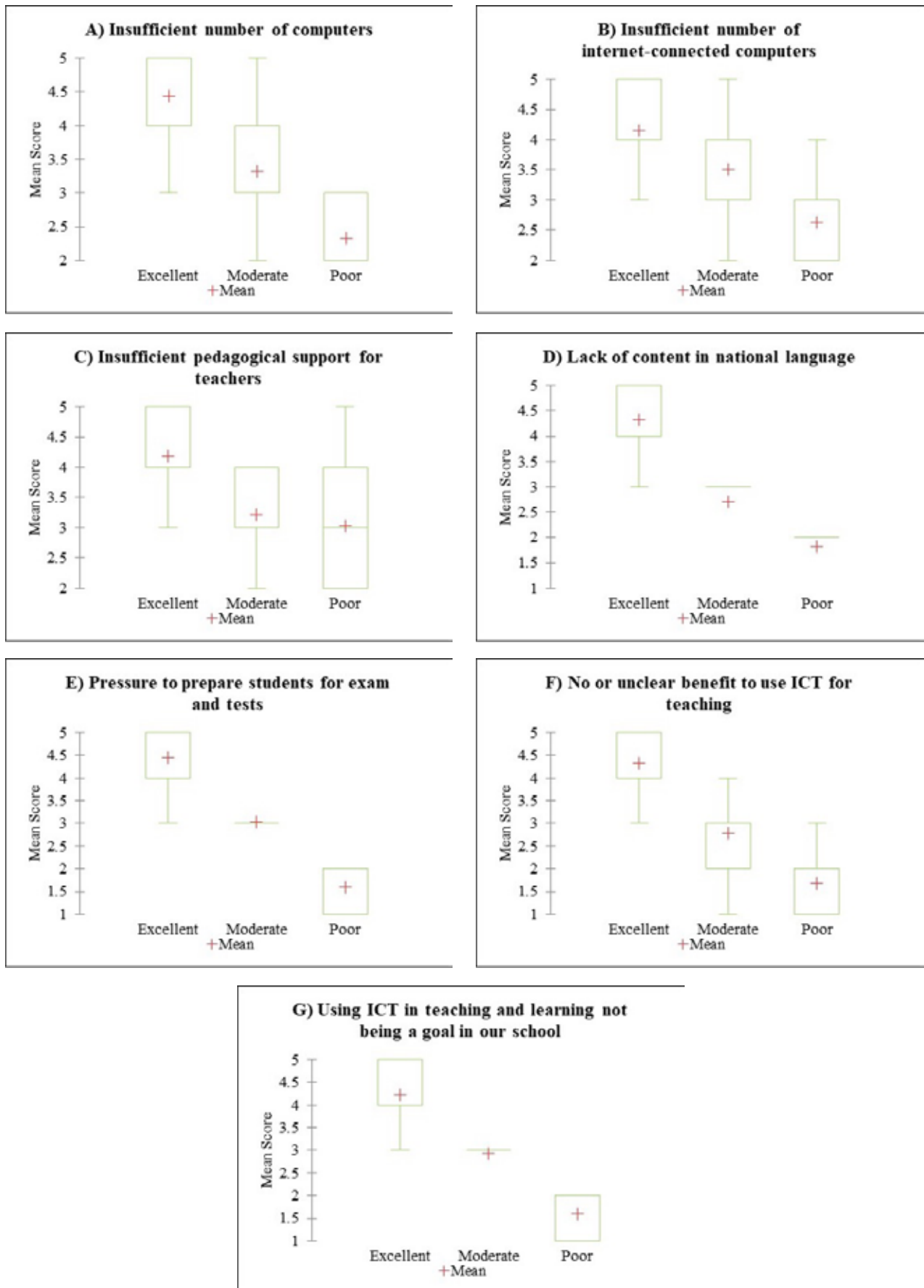
(seven independent variables), and 99.11% (seven independent variables), respectively.

Table 3 demonstrated seven out of eleven computer-related barriers were significant among excellent, medium, and poor clusters revealed by Discriminant Analysis using Backward stepwise with the highest percentage of classification correctness (99.11%). They include the insufficient number of computers (), insufficient number of internet-connected computers (), insufficient pedagogical support for teachers (), lack of content in the national language (), pressure to prepare students for exams and tests (), no or unclear benefit to using ICT for teaching () and perception of using ICT in teaching and learning not being a goal in their school (). The difference between the three clusters was visualized in Figure 2 below.

### Discussion

It is necessary to first consider the barriers that are present in the adoption process to understand the challenge of technology adoption in PE. A wide range of factors has been found to influence teachers' intention to adopt technology [6, 7, 12, 13]. They include accessibility to technology, perceived usefulness, perceived ease of use, subjective norm, facilitating conditions, and attitude towards use. Ensuring appropriate technology bears significance; however, attributing the lack of use of technology to limited resources is a huge challenge today. Undoubtedly, a stronger influencing factor exists among teachers.

Based on the findings, barriers such as an insufficient number of computers and an insufficient number of computers connected to the internet



**Figure 2.** Significant perceived barriers parameters for excellent, moderate, and poor groups applying technology in PE.

can be attributed to the cost factor. In PE, the cost factor is undoubtedly an unavoidable barrier to maximizing the use of technology in teaching and learning. Some teachers claim that technology is too expensive, making it unrealistic for PE [14]. Such thinking is a must, where PE teachers only seek information that supports their stance on technology use. When it comes to the cost of technology as well, the budget from the technology aspect for PE is also inadequate [15]. PE teachers have cited limited budget and access to appropriate technology as prominent barriers to technology adoption [4, 5, 16]. If the school director does not recognize ICT as a resource related to PE, the effect is the integration of technology into PE cannot be supported [17]. Indubitably, the principal's influence on the budget and integration of the whole school's curriculum in terms of PE cannot be underestimated [18]. The responsible party should aim to use technology that is realistic for all teachers on a budget, not just those who have the budget to buy technology can experience it. Teachers are also encouraged to identify low-cost and no-cost technologies that PE teachers can use. Such an approach may reduce the opportunity to develop the skills to use such technology in school [19].

The barriers of insufficient pedagogical support for teachers and lack of content in the national language can be related to organizational support factors. Venkatesh and colleagues [20] emphasized that organizational support is critical to the promotion of adoption. Technology adoption is likely to be perceived as too cumbersome if the organizational culture around technology and support for its use is perceived as inadequate [4]. When PE teachers, especially those who are novices or have not yet adopted the technology, attempt to integrate it, they need support to be successful. Teachers face many challenges during the technology adoption process (e.g., loss of technology skills, technology malfunction, students not on task). According to Zhao and Bryant [21], teachers lose the technology skills they acquired in a professional program if they do not receive further support. The loss of technical skills can become a barrier to the adoption of technology in the classroom. Niess [22] also pointed out the importance of teachers' ability to manage students' behavior during technology-based instruction. Such behavior management in a technology-integrated classroom is considered one of the most challenging aspects of teaching, especially for novice teachers who lack pedagogical knowledge. Teachers must learn to manage these challenges; otherwise, they risk making suboptimal decisions includes of maintaining the status quo. Ongoing support from experienced teachers can help teachers overcome the challenges and guide them to more effective use of technology.

The current finding also indicates the perceived

barrier of the pressure to prepare students for exams and tests leads to a poor degree of applying technology in PE. While this factor is often underestimated by policymakers, it has been supported by previous studies that mentioned the barrier to implementing educational technology can be a lack of time because of high-stakes testing [16] and a lack of training and time to learn [23, 24]. This demonstrates the need for quality technology integration training to help PE teachers successfully integrate technology into student learning. Since the use of ICT can mean an increased workload in terms of organizational aspects, the amount of time spent preparing for tests/exams and physical activity must be taken into consideration at PE. The majority of teachers recognize the positive aspects of technology in education but do not know how to implement it in their curriculum without sacrificing time for physical activity [25]. In this regard, technology should not replace PE instruction, but rather enhance it [26, 27]. It can be related to the level of teacher-student interaction, , the suitability of the learning environment, and learning commitment to the learning comfort [28].

In this sense, the teachers' belief that there is no or unclear benefit in using ICT in the classroom is another major obstacle. They also agreed that the use of ICT in teaching and learning is not a goal in their school. One study found that a positive attitude among teachers is a factor that enables the use of ICT [29]. The findings suggest that the basic prerequisite for its actual use is a positive attitude toward technology. The importance of attitude was discussed some time ago [30]. He examined the dependence of ICT use on attitudes toward technologies. Looking at the crucial role of attitude in the classroom, the extended results have shown that teachers' attitude is a key factor in the use of technologies in different environments [31, 32]. Due to this importance, studies have addressed the factors that create positive attitudes toward technology integration, and this suggests that more predictive resources need to be uncovered to facilitate the creation of positive attitudes [33]. Present bias makes it difficult for people to focus on long-term tasks and goals. Although many PE teachers are aware of the ability of technology to provide benefits, some PE teachers believe that the time it would take to learn and plan for technology integration would not justify its use. PE teachers must address several logistical issues, such as learning about the technology's features, planning how to introduce the technology to students, planning how to manage the technology, and considering how to use the data for pedagogical purposes, in order to effectively integrate technology into instruction [34, 35]. These processes are time-consuming, so some PE teachers believe the work is not worth it. Some PE teachers opine that they would rather engage students with

physical activity in the time it takes to implement the technology. Even though there is evidence that the technology can be beneficial to students, the cost of learning the technology and the time required to implement the technology are too high for some.

### Conclusions

Awareness of these barriers has implications for physical education, curriculum design, teacher training, and youth adolescent participation in the school environment. The positive opinions and attitudes shown by PE teachers toward ICT as educational tools could pave the way for improving their digital literacy, thereby increasing their rate

of use of these tools if they are provided with the appropriate technical resources and training.

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### Conflict of interest

No potential conflict of interest was reported by the authors.

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# Design and validation of a questionnaire to assess the Pedagogical Content Knowledge of Colombian Physical Education students in the practicum

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

## Abstract

**Background and Study Aim** In the training of Physical Education teachers, the practicum is considered a final stage of the training. The practicum implies an amalgamation and connection of the different knowledge acquired at the University and that, when contrasted with the real classroom practice, plays a fundamental role in the future professional development. The purpose of this study was to design and validate a questionnaire to measure the Pedagogical Content Knowledge of the Physical Education teacher trainee in the context of the practicum.

**Material and Methods** The participants were 146 practicum students of the Bachelor's degree program in Physical Education from four Colombian universities (115 men, 31 women, with an average age of 25.7 ± 5.2 years). A non-experimental descriptive cross-sectional study was conducted in two phases, the first one: content validity and the second phase related to the analysis of psychometric properties.

**Results** A Content Validity Ratio of .92 was presented, which indicates a very high content validity based on Lawshe's model and with a sample of 10 expert judges in the field. In the exploratory factor analysis by the principal component analysis method and varimax rotation, 7 dimensions were proposed, with 36 items explaining 66.78 of the total variance of the instrument. The internal consistency was very satisfactory ( $\alpha=.9$ ).

**Conclusions** The questionnaire provides a valid, trustable, and specific instrument, which allows identifying the knowledge that a Physical Education practice student has about pedagogy, context, evaluation, teaching strategies, students, experience, and content. Furthermore, understanding this type of knowledge is a precondition that can allow improving the curricular designs of Physical Education degree programs.

**Keywords:** pedagogical content knowledge, physical education, practicum, teachers, training, measurement instrument.

## Introduction

From the perspective of teacher training, the practicum represents the final moment of training. The practicum has a meaningful value for future professionals, since it is the first moment where the future teachers are given a leading role to face the reality of the classroom in all its complexity [1, 2, 3]. It is in the practicum when teachers in training, connect the different knowledge learned at the University defining their trajectory and teaching identity, with experiential, disciplinary, and curricular knowledge that is strongly influenced by the first professional experience [4, 5, 6]. The literature states that experiential learning is defined as the process by which the individual learns to act directly in a given situation through reflection on action as a process of knowledge production [7].

The practicum is recognized as one of the most

critical aspects of teacher training since it has a great impact on the quality of teachers [8, 9, 10]. The practicum represents a complex experience for students since it is experienced as an emotionally, physically, and interpersonally demanding process with significant consequences on the development of the teacher in training and their continuance in the profession [2]. The literature highlights the need for training programs to take responsibility for the tension between experience versus the current demands of teaching and learning, through the incorporation of activities explicitly directed toward understanding students' pedagogical knowledge through reflection on experience [11, 12, 13, 14, 15].

In the case of practical training in Physical Education, studies identify the elements that characterize this period, as well as the need to bring university classes closer to the school reality [1, 5, 16]. There is also a diversity of approaches to how school Physical Education should be organized,

which leads to a diversity of models and approaches that future teachers should know and experience. The discipline has characteristics where the context of content development is treated in different spaces than those of the other disciplines, adding to the complexity of teaching the specific content in Physical Education [17, 18, 19, 20].

In the field of practicum in Physical Education, the concept of Pedagogical Content Knowledge (PCK) is approached, which refers to the interactions with pedagogical purposes that take place in the classroom [21, 22, 23]. PCK tests the reflective action of the future teacher according to the needs of the students. Didactically, the contents are aimed at the appropriation of personal, theoretical, or practical elements by the students, and it is the teacher's function to adapt them to the dynamics of the context [24, 25, 26, 27]. PCK facilitates teachers and practicums to transpose disciplinary knowledge into teachable knowledge, so that it can be learned by their students, choosing the best examples, analogies, and demonstrations [14, 28].

Authors emphasize the need for initial training programs in Physical Education to implement pedagogical mechanisms that encourage trainee teachers' awareness of their relationship with their knowledge. The programs must contribute to the construction of PCK, through the management of all the knowledge in real teaching and learning situations [29, 30, 31]. This is the very heart of PCK, as it is the teacher who uses different resources, sources and elements of the context to integrate the background knowledge to be taught in a understandable way to the students [23].

PCK is directly influenced by the previous life, school, sport, academic (in the context of university training), and professional experiences to which trainee teachers of Physical Education have been and are subjected [30, 32, 33]. In initial training programs in Physical Education, environments conducive to the development of PCK can be designed based on the consideration of, for example, the place where pedagogical practices will be developed, the characteristics and number of students, etc. [1, 5, 16, 34]. Based on the propositions of authors [35, 36, 37], some inferences can be made about the probable tasks performed by the PCK in teaching practices, such as (i) receiving, through reflections, information from dilemmas that arise in teaching and learning situations; (ii) summoning knowledge in the knowledge base; (ii) interacting this knowledge and information; (iv) establishing action strategies; (v) intervening in the problematic situation; (vi) evaluating its results, and (vii) filing the new knowledge in the knowledge base.

It is generally accepted that PCK is constructed by managing the relationship between the knowledge base and the teaching and learning situation to make content knowledge understandable and

teachable for learners [20, 25, 26, 38]. However, some questions emerge regarding how PCK performs each of its different functions and enables the interaction between the knowledge base and the teaching and learning scenario. In Physical Education teaching, declarative knowledge, for example, refers to disciplinary, formal, and informational knowledge, such as that developed by biomechanics, physiology, motor learning theories or human development, and sports training theory [5, 32, 33]. This is what Shulman [21, 23] calls content or subject matter knowledge.

It is precisely this new knowledge that can be taught. Therefore, the future Physical Education teacher begins to demonstrate the improvement of his PCK and his competence to make his knowledge, related to the content, teachable and understandable to his students.

For all the above, the purpose of this study was to design and validate a questionnaire to measure the PCK, in the Physical Education teacher trainee in the context of the practicum.

## Materials and Methods

### *Participants.*

146 subjects (n) out of 206 (N) participated, and the study sample was stratified probabilistic [39], with a reliability of 95% ( $Z=1.96$ ), an error of 5%, and a probability (p) of 50%. All were practicum students of the Bachelor's degree program in Physical Education from four Colombian universities, during the first semester of 2022. They were 78.8% male and 21.2% female, with an average age of  $25.7 \pm 5.2$  years. Most of them are located in the ninth semester (37.0%); and they perform their school practice predominantly in the basic primary education cycle (46.6%), followed by basic secondary (29.5%). The project was approved by the bioethics committee of the University of San Buenaventura-Medellin N°14-12-2021. The research was conducted by the Resolution 8430 of 1993 of the Ministry of Health of Colombia [40] and the declaration of Helsinki for research on human beings [41].

### *Research Design.*

A descriptive non-experimental cross-sectional descriptive study was conducted [42]. Initially, content validity was carried out, consisting of a documentary review of studies and publications in specialized databases (Dialnet, EBSCO, Scopus, and Redalyc); from this review, the items of the initial questionnaire were established. Afterward, an expert judgment was carried out to guarantee the quality and adequacy of the items and dimensions [43] with the participation of 10 judges: two Chilean, one Spanish, and seven Colombian, all of them PhDs, teachers, and researchers. Finally, a pilot test of the questionnaire was carried out with 21 practicum students to check the structure of the

survey, and the functionality of the data collection procedures and to identify possible problems with the wording of the items [44]. After the pilot test, no changes were made and the participants were able to complete the questionnaire in approximately 15 minutes.

For the analysis of psychometric properties, the selected students signed the informed consent form, which indicated that participation was voluntary and that they could retire at any time during the study. The students filled out the questionnaire during the internship advisories.

*Statistical Analysis.*

For the analysis of content validity, the Lawshe model [45] was used, the reference value for a sample of 10 judges and an alpha of .05 was .62 or higher.

The Statistical Package for the Social Sciences (SPSS v.24) was used to perform the analysis. The Kaiser-Meier-Olkin (KMO) sample adequacy statistic (KMO) was applied the reference value to be considered as good was  $>.6$  [46]. In Bartlett’s test of sphericity was  $p <.05$  [47], to determine the possibility of generating a multidimensional instrument. An exploratory analysis was performed and principal component analysis (PCA) was used as an extraction method, based on a varimax rotation. The internal consistency and reliability analysis was done through Cronbach’s alpha, for each dimension and the questionnaire as a whole ( $\alpha >.7$ ) [48].

**Results**

In the first stage, 49 articles derived from an exploratory systematic review [48] were reviewed to determine the content validity, from which the initial items (43) were determined and which constituted the structure of the initial questionnaire. This initial version was evaluated by 10 experts on the subject, of the 43 items proposed, 5 of them obtained a score of less than .62 in the Content Validity Ratio (CVR) (Items: 14,15,25,35,37), which is why they were excluded. The other 38 items were rated as necessary, presenting CVR values between .7 and 1.0. The instrument presented a Content Validity Ratio of .92, a result that indicates a very high content validity [49], in other words, there is a high degree of consensus among the judges.

To determine the possibility of proposing a multidimensional instrument, the Kaiser-Meyer-Olkin (KMO) sample adequacy test was applied and its result was .883, which indicates a remarkable fit of the data [50]. Bartlett’s test of sphericity has a significance value of .000, which indicates that a multifactorial analysis can be performed [51].

For construct validity, a principal component analysis (PCA) and varimax rotation were performed, where 8 factors are extracted, however, one item does not charge in any of the dimensions and the other only one in dimension number 8, therefore,

they are removed from the questionnaire. We proceed again to perform the exploratory analysis with the remaining 36 items and at the end, 7 dimensions are proposed that explain a 66.780 of the total variance of the instrument, the result can be observed in Table 1.

**Table 1.** Factor analysis

Factor	Initial Eigenvalues		
	Total	% of Variance	Cumulated %
1	14.249	39.580	39.580
2	2.456	6.822	46.402
3	1.794	4.983	51.385
4	1.611	4.476	55.861
5	1.272	3.534	59.394
6	1.212	3.368	62.762
7	1.087	3.018	66.780

Regarding the matrix of rotating components (see Table 2), the first factor contains twelve items related to the knowledge and pedagogical application that the teacher in training should have of his or her discipline. Factor 2 groups six items that reference what should be known about the context and everything related to it. Factor 3 loaded three items related to knowledge of assessment (co-assessment, self- assessment, and hetero-assessment). Factor 4 groups five items associated with teaching strategies, especially mentioning games and sports. Factor 5 has five items that refer to the knowledge of students in terms of their characteristics and requirements. Factor 6 has three items that refer to experiential knowledge, from the reflection and dialogue of knowledge that takes place in the practicum. Finally, factor 7 groups three items that refer to the knowledge of procedural, attitudinal, and transversal contents.

When establishing the reliability of the questionnaire it presented a value of .952 in Cronbach’s alpha model, which indicates a very good internal consistency [52]. For each of the dimensions Cronbach’s alpha had a satisfactory rating [53] (see Table 3): pedagogical knowledge of Physical Education ( $\alpha=.909$ ); Knowledge of context ( $\alpha=.829$ ); Knowledge of assessment ( $\alpha=.882$ ); Knowledge of teaching strategies ( $\alpha=.848$ ); Knowledge of students ( $\alpha=.825$ ); Experiential knowledge ( $\alpha=.710$ ); and Content knowledge ( $\alpha=.741$ ). When establishing the relevance of each of the items by eliminating any of them, the value of Cronbach’s alpha does not improve the internal consistency of the total dimension, so the items that compose each of them are preserved.

**Table 2.** Matrix of rotated components of the factorial analysis

Ítem	M	SD	F1	F2	F3	F4	F5	F6	F7
1	3.507	.7071	.781						
2	3.678	.6207	.683						
3	3.589	.6504	.675						
4	3.445	.7147	.626						
5	3.336	.7815	.623						
6	3.61	.6365	.613						
7	3.507	.9487	.596						
8	3.144	.9321	.59						
9	3.486	.6971	.539						
10	3.425	.7224	.495						
11	3.5	.6873	.494						
12	3.349	.8436	.466						
13	3.384	.7725		.732					
14	3.295	.7805		.725					
15	3.466	.7716		.638					
16	3.377	.7441		.637					
17	3.315	.9667		.606					
18	3.377	.9032		.534					
19	2.986	1.1325			.815				
20	3.116	1.1357			.814				
21	2.932	1.1426			.755				
22	3.219	1.0272				.832			
23	3.418	.8201				.821			
24	3.445	.8224				.664			
25	3.747	.5967				.463			
26	3.281	.869					.737		
27	3.301	.8083					.59		
28	3.384	.8571					.493		
29	3.514	.6771					.434		
30	3.411	.8442					.417		
31	3.26	.9326						.789	
32	3.253	1.0879						.623	
33	3.521	.7068						.442	
34	3.37	.7792							.626
35	3.185	.8789							.531
36	3.116	.8984							.458

## Discussion

The purpose of this study was to design and provide initial evidence of the validity and reliability of a tool to identify PCK in the Physical Education (PE) trainee teacher in the context of the practicum. The PCK is of vital importance given that it represents the knowledge that teachers use in the teaching process, distinguishing the teacher of a designated subject from a subject specialist [54].

PE is a subject that is approached very differently from other subjects [55], also in the practicum is where the teacher in training is fully immersed in the reality of the school [56]. As referred to by Kim [19], little research has been conducted to examine how the PCK of trainee teachers of EF develops, therefore it is necessary to unravel those initial levels, which reveal their understanding of the content, the students, and the context before they leave their training programs.

**Table 3.** Questionnaire reliability statistics (Cronbach’s Alpha)

Dimension	Items	Alpha if the item is removed	Cronbach’s alpha of dimension
Pedagogical knowledge of Physical Education.	1. I consider the interaction between students as an important element in the assessment of the class.	.901	.909
	2. The activities that I implement in the central part of the class are aimed at achieving the purpose of the class.	.898	
	3. I make corrections when actions and/or activities are not properly executed by students.	.900	
	4. I take into account individual-type performance in class assessment.	.903	
	5. I assess the procedures and actions performed by students in the classroom	.899	
	6. I determine actions from less to more complex in the activities I develop in class.	.903	
	7. I approach the concepts of healthy habits and health as an important component of the class.	.911	
	8. I assess or consider at the end of the period, what I found in the input behavior.	.902	
	9. I propose motor actions for students to solve by themselves.	.904	
	10. I provide feedback on the activities and contents worked on in class.	.901	
	11. I use different didactic strategies for the approach of the contents.	.900	
	12. The assessment I perform corresponds to the purposes and contents of the class.	.902	
Knowledge of context	13. I improve my teaching practice by applying elements gathered from Physical Education literature.	.785	.829
	14. I improve my teaching practice by applying elements of pedagogical literature.	.791	
	15. I use the return to calm and rest activities in the didactic approach of the class.	.806	
	16. I consider the differences of the students in the group as a central element when developing the class.	.802	
	17. I consult my advisor about actions I need to implement in my pedagogical practice.	.815	
	18. I consult my cooperador about actions I need to implement in my pedagogical practice.	.813	
Knowledge of assessment	19. I include the co-assessment	.832	.882
	20. I include the self-assessment	.817	
	21. I include the hetero-assessment	.872	
Knowledge of teaching strategies	22. I use sports as part of the content area.	.801	.848
	23. I consider that sport and its different manifestations are a method for approaching the classroom.	.769	
	24. I use leisure, recreation and free time as part of the contents of the area.	.790	
	25. I consider the game to be an important means of approaching the class.	.852	

**Table 3** (continued)

Dimension	Items	Alpha if the item is removed	Cronbach's alpha of dimension
	26. I recognize for each level and grade level, the contents that should guide the class.	.749	
	27. I recognize at each level and grade level, the purposes that should guide the class.	.761	
Student knowledge	28. I listen to the recommendations, needs and expectations of the students regarding the class and adapt them based on the possibilities of action according to the planning, purposes and contents according to the grade level.	.819	.825
	29. I plan actions in the area according to the age and characteristics of the students.	.819	
	30. What I address in class is consistent with the comprehensive plan of the Physical Education area.	.790	
Experiential knowledge	31. I dialogue with teachers who are part of the educational institution about actions that can improve my pedagogical practice.	.545	
	32. Dialogue with other practitioners about what develops in the pedagogical practice.	.645	.710
	33. I record and reflect on what I do in class.	.660	
Content knowledge	34. Development of attitudinal contents in the classroom	.589	
	35. Development of conceptual contents within the class.	.696	.741
	36. I approach in a complementary way transversal contents through actions and activities of the class.	.684	
Total questionnaire.952			

This is the first study of this type that investigates the PCK of teachers in training in a Bachelor's degree program in Physical Education in Colombia. This subject has been of great interest, but in subjects such as Biology [57], Physics [58], Mathematics [59], Chemistry [60], among others. Thus, it becomes a study that serves as a starting point to lay the foundations and pave a route toward the improvement of the formative processes and curricular structures of the Bachelor's degree programs in FE.

The starting point for the design was a documentary analysis, which focused on PCK and the review of models such as Gess-Newsome and Carlson [61]; Gess-Newsome and Lederman [62]; Grossman [63], to name a few. However, emphasis was placed on studies that designed and validated instruments that measured the PCK construct in the area of Physical Education, such as that of Almonacid-Fierro et al. [64], which was developed for practicing teachers in Chile, and that of Meier [65] constructed for teachers in training in Germany. Subsequently, the expert panel methodology was used, and their comments from different approaches and perspectives enhanced the instrument [66], also

was important because they pointed out that most of the items constructed are clear, concise, and relevant, which highlights the content validity [65].

The exploratory analysis by the principal components method and varimax rotation this had satisfactory results, as do other instruments in the area [64, 67, 68]. The items loaded on seven factors that account for the PCK construct:

- the first is Pedagogical Knowledge of Physical Education, a component that refers to the teacher's understanding of the subject, of the selection and sequencing of tasks, which he/she can use to teach [69, 70, 71, 72];
- the second is Knowledge of the context, which includes listening to the perceptions of teachers who are more experienced and have been in school longer and the adaptation of an evidence-based practice to the different educational contexts in which they are [30];
- then there is the Knowledge of assessment with a determining characteristic in the formative during the process [73];
- on the other hand there is the Knowledge of teaching strategies, which highlights the ways of making something understandable to others

- [65];
- then the Knowledge of students, which includes knowledge of their developmental characteristics, the characteristics of their culture [30];
- there is also Experiential Knowledge, where the reflection made by the teacher in training is an essential input for the articulation of strategies relevant to the context and becomes a guarantor for the construction of PCK [74];
- and finally, Content Knowledge, refers to how content is developed and presented, it can be seen in the decisions a teacher makes about what and when to teach specific content [75].

## Conclusions

The present study provided evidence of the validity and reliability of the questionnaire to assess PCK in Colombian Physical Education students in the practicum. The PCK is a key component in the competence of a teacher and the process of unveiling in terms of a particular field what considerations, competencies, and skills a future teacher should possess to face his or her pedagogical work.

The questionnaire seems to have the potential to identify the knowledge that, about pedagogy, context, assessment, teaching strategies, students,

experiential, and content, a student who is training to be an EF teacher has. Understanding this type of knowledge is a precondition for laying the foundations and paving a path for the improvement of the training processes and curricular structures of the Bachelor's degree programs in PE.

Despite the importance of PCK, in Colombia, the subject is still incipient in the area of PE. Therefore, one of the most relevant aspects of this study is the development of a valid and reliable instrument to evaluate PCK in students in training, specifically in the practicum.

It is important to note that this study is an initial validation of the questionnaire in a group of students, at a certain time and with particular characteristics. Therefore, further studies considering other samples, cultures, and languages are recommended.

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## Conflict of interest

The authors declare no potential conflicts of interest.

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# The effects of experimental program on the explosive strength of lower limbs in male adolescents

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## Abstract

**Background and Study Aim** Various experimental programs for the development of motor skills are present in sports activities. Explosive strength can be defined as the ability to produce maximum force as soon as possible, and it represents an essential factor in activities where it is necessary to increase the acceleration of the body mass, the mass of specific body parts, or of an external object. The aim of study – to determine the effects of an experimental program on the explosive strength of lower limbs in male adolescents.

**Material and Methods** One hundred and one male adolescent (aged 19 years  $\pm$  6 months; body height 181.43  $\pm$  7.42 cm; body mass 80.08  $\pm$  10.07 kg) were recruited and randomly divided into two groups: experimental group (E; N=48) and control group (K; N=48). The E group performed the experimental program which lasted fifteen weeks and consisted of three 60-min training sessions per week. All participants were tested on Squat Jump (SJ), Countermovement Jump (CMJ), Countermovement Jump with arms (CMJa) and Continuous Jump with Straight Legs (CJSL). The four tests were performed using a Kistler force platform to measure Quatro Jump Bosco Protocol Version 1.0.9.2 and gave us data about the jump height, number of jumps for 15s, average power jump and peak power jump. The multivariate analysis covariance (MANCOVA) and follow up analysis covariance (ANCOVA) were used to analyze the data.

**Results** The results of MANCOVA showed statistically significant differences ( $p \leq 0.001$ ) between the E and K groups in all systems of variable lower limb explosive strength in male adolescents. In addition, results of ANCOVA showed statistically significant differences ( $p \leq 0.001$ ) in SJ, CMJ, CMJa and CJSL in favor of the E group compared to the K one.

**Conclusions** The results of this research show that a fifteen-week experimental program can lead to significant improvements in lower limb explosive strength in male adolescents.

**Keywords:** plyometric training, complex training, motor abilities, adolescents

## Introduction

Explosive strength can be defined as the ability to produce maximum force as soon as possible, and it represents an essential factor in activities where it is necessary to increase the acceleration of the body mass, the mass of specific body parts, or of an external object. The explosive strength is genetically determined, but his development can be influenced by the training process. In the adolescent period (from 10 to 24 years of age), explosive strength of the lower limbs can be developed, however, the training program has to be properly designed [1].

Verhoshanski & Tatyana [2] designed plyometric training and thus caused a revolution in methods for developing lower limb explosive strength. Since then, and until the present, there have been many studies that confirmed that plyometric training improves the explosive strength of the lower

limbs of adolescents (athletes, non-athletes and recreational athletes). More precisely, Impellizzeri et al. [3] showed that 4 weeks of plyometric training improves the lower limb explosive strength in the form of jumps (squat jump and countermovement jump). While Ronnestad et al. [4] stated that a combination of plyometric training and specific strength training is also efficient in developing the explosive strength of the lower limbs of adolescents (athletes). Furthermore, Blattner & Noble [5] stated that isokinetic training can produce similar effects as plyometric training on the vertical jump of adolescent athletes. In addition, should not be neglected complex training which involve a combination of heavy and light loads, as well as that complex pair of exercises represents a good strategy for increasing explosive strength through increased neuromuscular activity [6].

Other studies state that plyometric training effectively affects the explosive strength of the limbs in adolescents [7, 8, 9, 10]. So Fischetti et al.

[7] studied specific acute adaptation to vertical jump in boys aged 12–14 years. The authors concluded that adolescents may benefit more from exposure to a combination of plyometric and resistance training methods. Peitz et al. [8] noted that various types of resistance training (e.g., bodyweight, free weights) are effective in improving muscle strength (e.g., maximal voluntary contraction) in untrained children and adolescents. Singla et al. [9] studied the effect of plyometric training on neuromuscular adaptation in cricketers of different age groups. The authors note that adolescents under 18 years of age showed significantly greater improvements in upper body balance and upper body strength than adults aged 18–25 years. Flavio et al. [10] argue that 4 weeks of plyometric training is not enough to significantly improve vertical and horizontal jump speed and height for adolescents aged 14 to 17 years. The results of these studies are in good agreement with other studies involving adolescents [3, 4, 5].

Based on the above, it can be obtained that there are a number of different training methods that are applied in developing the lower limb explosive strength of adolescents (athletes, recreational athletes, and non-athletes), however, plyometric training is the most applicable one.

The research question is whether plyometric training will have better effects if it is combined with other training types, which include starting accelerations, running with loads, jumps with loads, and locomotor system stabilization exercises. Therefore, the aim of this study was to determine the effects of the experimental program on the explosive strength of the lower limbs of male adolescents.

## Material and Methods

### *Participants*

The sample of participants consisted of 101 male adolescents (age  $20.03 \pm 1.16$  years; body height  $181.43 \pm 7.42$  cm; body mass  $80.08 \pm 10.07$  kg) from the student population of the University of Novi Sad. During the selection of respondents, 120 students were selected and tested at the initial measurement, however, after a fifteen-week treatment, there was a respondent dropout of 15.83% (19 respondents). Therefore, the study sample included 101 participants who fully implemented the experimental program and were present at the initial and final testing. The participants were randomly divided into two groups: experimental (E,  $n=48$ ) and control (K,  $n=53$ ) groups. The respondents from E group were subjected to a fifteen-week training program three times a week, while the subjects from the control group, in addition to their daily activities, voluntarily engaged in sports and recreational activities (football, basketball, volleyball, tennis, running...), 2-3 times a week, so it was a control treatment that was not

programmed by the author. The testing procedures were performed following the ethical norms and standards laid down in the Declaration of Helsinki.

### *Research Design*

#### *Procedure*

The measurement of lower limb explosive strength was performed before the experimental program, and after a period of 15 weeks. The testing was conducted at the Sports Center of the Faculty of Sport and Physical Education, Novi Sad from 8 A.M. to 3 P.M. in one day. The air temperature in the Sports Center ranged from 22 to 25°C. The respondents came in groups of 10 participants and they did a standard 15-minute warm-up before the testing. The testing session began with anthropometric measurements (body height and body weight). The participants were then instructed to assess the lower-body muscular strength (Squat Jump, Countermovement Jump, Countermovement Jump with Arms, and Continuous Jump with Straight Legs). The participants performed 3 trials for the tests, with a recovery of approximately 3 minutes between the trials. All tests were performed using the same measuring instrument i.e., a Kistler force platform (Quattro Jump, 9290, Switzerland). The initial and final testing was carried out under the same criteria so that the results could be compared [11]. The measurement was performed by assistants appointed at the Faculty of Sport and Physical Education.

#### *Variables and testing*

The Squat Jump (SJ), Countermovement Jump (CMJ), Countermovement Jump with Arms (CMJa) and Continuous Jump with Straight Legs (CJSL) were determined by a force platform (Kistler Instrument AG, Quattro Jump, 9290, Switzerland). This platform has a Bosco protocol [12], which objectively allows measurements of the following: high jump (cm), number of jumps for 15s ( $n$ ), average jump power (W/kg) and peak power (W/kg). Each participant performed 3 trials of each jump and the best result was recorded for statistical analysis.

#### *Experimental program*

The experimental program was conducted over a period of 15 weeks (3 times a week - on Monday, Wednesday and Friday). The respondents were required to perform exercises at a technically high level during the entire experimental program, which enabled the respondents to avoid injuries, and the effects of the exercise to be raised to the maximum level. Four mesocycles represented the basis for the experimental program implementation.

In *the first mesocycle*, the implementation was focused on the development of basic abilities that should create the basis for the specific nature of the mesocycle that will follow after this period. The nature of the work in *the second mesocycle* was focused on the transition from basic to specific

work. Special attention was paid to the introduction of specific exercises for the development of specific abilities.

The development of specific abilities was the basis of *the third mesocycle*. In the third mesocycle, exercises of a dynamic explosive nature were performed, which contributed to a further increase in the abilities and efficiency of the experimental program.

*The fourth mesocycle* focused on the implementation of exercises aimed at raising the abilities of a specific nature to the highest level.

Two-foot jumps were performed in the first five weeks (twice a week) in the volume of 60 jumps per training session, as well as in a combination of two-foot hurdle jumps and two-foot standing long jumps. In the other five weeks, two-foot jumps were performed twice a week (weeks 6, 8 and 9) and once a week (weeks 7 and 10). In the final three weeks of the experimental program, two-foot jumps were mostly carried out twice a week.

Single-leg jumps were performed once a week (in the first five weeks). In the other five weeks, single-leg jumps were performed twice a week (weeks 7 and 10) and once a week (weeks 6 and 9). In the final three weeks of the experimental program, the number of single-leg jumps increased to 2 times a week. Single-leg jumps were performed less often in the first 6 weeks (3 treatments during 6 weeks), and as the respondents' ability increased the number of training treatments also increased to 11 in the last 9 weeks. The total number of jumps per training session was increased to 80 in the second 5 weeks, and in the last 5 weeks, the participants achieved a volume of 100 jumps per training session. Alternate-foot jumps were performed in combination with two-foot jumps and single-leg jumps, whereby the dynamics of training from the 5th week until the end of the experimental program was carried out alternately with one training session per week (on odd-numbered weeks), while two training sessions were performed on even-numbered weeks. Horizontal and vertical jumps were done separately, and sometimes in combination. The jumps were combined in order to avoid motor stereotypes and to direct the dynamic force of an explosive striking nature forward and upwards. They were realized through jumps over the hurdles with a distance of 6-9 meters (vertical hurdle jump).

The horizontal jump between the hurdles should have been performed in 2-3 jumps, depending on the length of the distance.

Resistance jumping exercises were performed in a smaller volume due to the complexity and difficulty of the performance. They were realized by the respondents' performing jumps with a vest of adequate weight (2-10 kg, depending on their body mass; 2% at the beginning of the experimental

program, and up to 10% at the end of the program). Resistance jumping exercises served as basic preparation (in the first 5 weeks) for plyometric jumping exercises. In the first 5 weeks, plyometric jumps were performed only in the 4th week, and in the second 5-week period, the number of plyometric training sessions was increased to 5 training sessions, and to 7 training sessions in the last 5 weeks. Plyometric training sessions were realized through jump-offs and landings from jump boxes of adequate height (in the first 5 weeks the height was 60 cm, in the second 5 weeks it was 80 cm and in the last 5 weeks it was 100 cm). After the landing, the respondents mostly performed two-foot jumps over the hurdle, which was also lower in height (76 cm) in the first 5 weeks, and with a gradual increase, it reached a height of 100 cm by the end of the treatment.

Exercises that include starting accelerations were used as a means to improve the technique and coordination of the performance of the assigned exercises and the number of training sessions was gradually decreased during the experimental program.

Between the 2nd and the 11th week, exercises that include resistance running activities were performed. This was realized by running uphill at a distance of 50-200m. The locomotor system stabilization exercises were performed during the entire experimental program, with special reference to the stabilization of the ankle joint, knee joint, pelvis and spine, as the pillar of the entire locomotor apparatus.

As the last, but not the least important type of activity, general physical preparation was done during the experimental program. The target muscle groups included the abdominal muscles, back muscles, and the muscles of the arms and shoulder girdle. The objective of this activity was to strengthen these muscle groups through the implementation of as many different ways of performance as possible. The intensity and volume of work during the experimental program were designed according to Malacko [13].

A schematic representation of the plan of the experimental program can be seen in Table 1.

#### *Statistical analysis*

Statistical analyses were performed with SPSS software (Version 20.0; IBM SPSS, Inc., Chicago, IL, USA). Arithmetic mean (Mean) and standard deviation (SD) were calculated for all variables. To determine the effect of the applied experimental treatment (training model), a multivariate analysis of covariance (MANCOVA) was applied for the entire system of applied variables, while individual differences in the analyzed variables were determined by the application of a univariate analysis of covariance (ANCOVA).

**Table 1.** Plan of the 15-week experimental program

WEEK TYPE OF ACTIVITY	I		II		III		IV		V		VI		VII		VIII		IX		X		XI		XII		XIII		XIV		XV	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Two-foot jumps	x	x	x	x	x	x	x	x	x	x	x		x		x	x	x		x		x	x	x		x	x	x		x	x
Single leg jumps					x				x	x			x	x	x		x	x					x	x	x		x	x	x	
Alternate foot jumps	x	x	x		x		x		x		x		x	x	x		x		x	x	x		x		x	x	x		x	x
Horizontal jumps	x	x	x		x		x		x		x		x	x	x		x		x	x	x		x		x	x	x		x	x
Vertical jumps	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Combination of horizontal and vertical jumps			x		x				x	x	x	x			x		x		x	x					x	x	x		x	
Resistance jumping exercise	x	x	x		x				x	x	x		x	x			x		x	x	x				x	x	x		x	
Plyometric exercise							x				x		x		x		x		x		x	x	x		x		x	x	x	
Starting accelerations	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Resistance running exercise			x	x	x				x	x	x	x			x		x		x	x	x		x	x						
Locomotor system stabilization exercise	x	x	x		x	x	x	x	x		x	x	x	x	x		x		x	x	x		x	x	x		x	x	x	
General physical preparation	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Abbreviation: 1 – Monday; 2 – Wednesday; 3 - Friday

**Results**

Table 2 presents the results of the MANCOVA showing us that there is a statistically significant difference (P=0.000) between the E and K groups in the entire system of variables of the lower limb explosive strength. Regarding the individual inspections of the variables in Table 2, it can be shown that a statistically significant difference (p=0.000) between the groups (E vs. K) in all variables: SJ (cm); CMJ (cm); CMJa (cm); CJSL (cm); CJSL (n); CJSL average power (W/kg) and CJSL peak power (W/kg).

Table 3 shows the corrected means as well as the confidence intervals of the individual variables of the explosive strength of the lower limbs after the treatment. The fact that the confidence interval contains zero in none of the variables leads to the conclusion that there is a difference between the E and K groups of respondents: SJ (cm) (3.17 / 4.27), CMJ (cm) (3.34 / 4.15), CMJa (cm) (1.22 / 2.41), CJSLn (n) (1.45 / 2.30), CJSL (cm) (3.18 / 3.76), CJSL peak power (W/kg) (3.35 / 4.52) and CJSL average power (W/kg) (3.42 / 4.26). Also, inspecting the results presented in Table 3 of the corrected means of the analyzed variables, it can be concluded that the E group had higher values of the variables compared to the K group and that the experimental program

was successful.

**Discussion**

Each training process, as well as our experimental program, must be an organized and planned time-limited process, including constantly changing cycles. The end result expected is that the body is transformed and transferred from the initial condition to a new final one. Therefore, the aim of this study was to determine the effects of the experimental program on the explosive strength of the lower limbs of male adolescents. The main findings of the study show that a 15-week experimental program improves the lower limb explosive strength in adolescent males.

The results of this study show that there is a significant difference between the E and K groups in all variables of the lower limb explosive strength (p=0.000) in favor of the E group. The variables of the explosive strength of the lower limbs were obtained by testing different types of jumps, whereby the height of the jump, the peak power of the jump, the average power of the jump, the number of jumps, etc. were taken into account. The results of the corrected means and the confidence intervals indicate that all differences in the progress of the lower limb explosive strength were determined in favor of the

**Table 2.** Difference between the E and K groups in the variables of lower limb explosive strength after the treatments applied

Variables	E (Mean±SD)		Δ (%)	K (Mean±SD)		Δ (%)	F*	p
	Initial	Final		Initial	Final			
SJ (cm)	43.23±4.34	47.03±4.57	8.79	44.02±4.41	43.85±3.73	-0.39	170.00	0.000*
CMJ (cm)	46.87±4.77	50.52±4.93	7.79	47.72±4.89	47.70±5.44	-0.04	275.79	0.000*
CMJa (cm)	54.50±6.36	58.67±5.92	7.65	53.81±4.22	56.35±4.58	4.72	33.34	0.000*
CJSL (cm)	36.75±3.70	40.36±3.72	9.82	37.67±3.50	37.55±3.73	-0.32	57.85	0.000*
CJSLn (n)	19.48±1.75	21.50±1.57	10.37	19.34±2.09	19.53±2.23	0.98	61.51	0.000*
CJSL average power (W/kg)	40.72±5.82	44.80±5.98	10.02	41.22±5.31	41.35±5.27	0.32	287.62	0.000*
CJSL peak power (W/kg)	46.61±6.94	51.39±6.04	10.26	47.82±5.71	48.32±4.85	1.05	167.63	0.000*

F= 167.763; p=0.000

Abbreviation: E – experimental group; K – control group; SJ – squat jump; CMJ – countermovement jump; CMJa - countermovement jump with arm swing; CJSL – continuous jumps with straight legs, average jump height; CJSLn - number of continuous jumps with straight legs; CJSL average power – continuous jumps with straight legs, average power; CJSL peak power – continuous jumps with straight legs, maximum jump power; F\* – test for univariate analysis of covariance, \* – statistically significant difference between the groups within one variable (ANCOVA) ( $p \leq 0.000$ ); Δ% = individual progress in percentage; F – test for multivariate analysis of covariance, P – level of significance of differences between the groups in the system of variables ( $p \leq 0.000$ ).

**Table 3.** Corrected means and confidence intervals of the E and K groups in the variables of lower limb explosive strength after the treatments applied

Groups	Variable	Corrected means	Confidence interval
E K	SJ (cm)	47.31 43.59	3.17 4.27
E K	CMJ (sm)	51.01 47.26	3.34 4.15
E K	CMJa (cm)	58.39 56.57	1.22 2.41
E K	CJSLn (n)	21.45 19.57	1.45 2.30
E K	CJSL (cm)	40.73 37.26	3.18 3.76
E K	CJSL average power (W/kg)	51.87 47.93	3.35 4.52
E K	CJSL peak power (W/kg)	45.02 41.18	3.42 4.26

Abbreviation: E – experimental group, K – control group

E group, which leads us to the conclusion that the experimental program influenced the explosive strength of the lower limbs to develop significantly. All the levels of significance of the differences found in this system of explosive strength are very high ( $p = .000$ ), which can lead us to the conclusion that the two groups were significantly different. The K group had no programmed treatment but it included the respondents who, in addition to daily life activities, only engage in low-intensity recreational activities. On the other hand, the experimental program lasted for an entire mesocycle (15 weeks), which, in the training process, is quite enough to achieve significant effects regarding the development of motor skills that are not innate to a large extent. The results of this study are in accordance with the research of [10] where we can find that the respondents increased the peak power of the jump, vertical jump, speed, and agility after the two-month treatment applied. Also, Kobal et al. [14] showed that vertical jump (CMJ height) increases regardless of the training scheme (complex training, traditional training, contrast training, training with loads – plyometric alternately). It has been assumed that rapid improvements in vertical jump ability occur due to short-term neuromuscular adaptations induced by all training regimens [9, 15]. In fact, some studies have already reported that improvement in vertical jump ability is accompanied by an increase in peak power of the jump [7, 16, 17, 18]. The maximum increase in jump power amounted to approximately 50%, which is higher than the values previously reported in the literature, using isolated regimens of strength training [19] and plyometric training [20]. Accordingly, Villarrel et al., [21] concluded that improvements in lower limb explosive strength are significantly greater when plyometric exercises are performed in conjunction with strength training, which has been confirmed by [22]. The authors [22] stated that strength training combined with weights and plyometric exercises has the greatest impact on the explosive strength of the lower limbs. According to these authors, this combination may optimize neuromechanical factors that can improve maximum strength performance, due to the possible summation of training adaptations (provided by

both strength training and plyometric training) to neuromuscular performance. In the study conducted by [21], young football players were trained at 70% 1RM (on average during all 8 weeks), which can be considered high-intensity training. It should be noted that the range of loads used herein (i.e., 60–80% 1RM) was chosen in accordance with the recommendations given in a specific meta-analysis, which highlighted that this training intensity is capable of enhancing the acute neuromuscular responses induced by PAP [23]. Also, a combination of strength training and plyometric exercises has been shown to be effective for improving sport-specific performance. However, there is no consensus on the most effective way to combine these methods in the same training session in order to achieve greater improvements in neuromuscular performance. Therefore, new research is always welcome. And this study has shown that if plyometric exercises, starting acceleration exercises and stabilization exercises are performed during one training session, the explosive strength of the lower limbs of adolescent males can be significantly improved. This research is a novelty compared to other studies. In other studies, [19, 21], exercises with loads and plyometric exercises were performed during one training session, whereas in this study plyometric exercises, acceleration exercises and exercises for the development of body stabilization were performed during one training session. Therefore, a combination of plyometric exercises with stabilization exercises and acceleration exercises can significantly improve the lower limb explosive strength in adolescent males.

### **Conclusions**

It can be concluded that this carefully planned 15-week experimental program, which includes plyometric exercises, resistance jumping exercise, exercises for the development of acceleration and stabilization exercises, was very successful for the development of explosive strength of the lower limbs in respect of the given sample of respondents (adolescents). During the implementation of the experimental program, all principles of the training process and its periodization were respected.

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# The effectiveness of using power fitness training loads to increase adaptive reserves of female athletes in hand-to-hand combat

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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** One of the main aspects of improving the special training of athletes in hand-to-hand combat is increasing functional reserves in conditions of power loads. Study Purpose - to study the peculiarities of adaptive body changes and the level of special training in female athletes of hand-to-hand combat using power fitness programs with different structure, parameters, and means.

**Material and Methods** We examined 36 female athletes (18-20 years old) who had been engaged in hand-to-hand combat for the last 4 years. We divided these women into two groups, 18 people in each group. Groups used completely different power fitness training programs. We used methods of testing special training (the number of accurate kicks on the mannequin for 30 s) and laboratory monitoring of blood biochemical parameters (cortisol and LDH) before and after training load during 3 months. Group A used the standard power fitness training program for women of this age (exercises on simulators). Group B used well-known exercises with their own body weight with a complete change of kinematic and dynamic characteristics of the technique during 3 months of training.

**Results** The obtained results showed that indicators of special training positively changed by 10.4% ( $p < 0.05$ ) in group B athletes. At the same time, the studied indicator increased by 2.2% compared to initial level in group A athletes. At the end of the study, we observed an increase in cortisol level in the blood serum of group B athletes in response to physical stimuli. This was almost 10 times lower than the results recorded in group A. The results of monitoring LDH activity in the blood serum showed that its level increased by 19.5% ( $p < 0.05$ ) during the entire study period only in group B athletes. The controlled indicator remained almost unchanged in group A. The dynamics of the studied steroid hormone and enzyme in the blood serum in group B indicated an increase in the level of organism resistance to training loads under specified conditions of muscular activity and their pronounced adaptive changes.

**Conclusions** Determining the most effective power fitness training program for special training of female athletes in hand-to-hand combat, will help to increase their adaptive body reserves and their level of fitness. For this using different in structure and parameters training load.

**Keywords:** hand-to-hand combat, adaptive changes, power fitness, female athletes, training programs.

## Introduction

Modern aspects of improving the mechanisms of training in hand-to-hand combat and other martial arts aimed at achieving maximum results in the shortest possible time. Such an approach demand from scientists and coaches to find effective ways to optimize the training system [1, 2, 3, 4].

One of the important factors of improving the training process is a reasonable choice of specialized

training programs aimed at increasing the functional reserves of athletes [5, 6, 7, 8], or certain physical qualities [6, 9, 10, 11, 12].

In recent years, a number of martial arts experts [13, 14, 15] have studied the mechanisms of solving this problem and the possibility of implementing the results in practice. In turn, most of these scientific works [16, 17] presented the study of ways to improve training and competitive activities by correcting the means, methods, load parameters, mainly in highly skilled hand-to-hand athletes.

However, modern specialists in this field have

not paid enough attention to solving the problem of finding effective and safe ways to increase the functional capabilities of athletes. This applies the stage of specialized basic training of women in hand-to-hand combat.

The relevant areas of research in this field relate to using power training, specialized methods, tools and programs of power sports in the process of special training in martial arts. Also studying their impact on performance in competitive activities [3, 18, 19].

There are several controversial issues concerning the process of power training of athletes in hand-to-hand combat and other martial arts:

- indicators of volume and intensity of training loads;
- number of sets and approaches;
- the effectiveness of exercises (on simulator, with dumbbells, with own weight);
- increasing body reserves.

This is especially true for female athletes, as the level of resistance to stress stimuli in the anaerobic mechanism of energy supply is quite low and there is a great risk of failing the adaptation process [9].

In this context, it is recommended to pay attention to the following features of strength fitness for women:

- Resistance training under dynamic conditions can trigger delayed adaptation to training conditions [20];
- The increase in maximum oxygen consumption results in an increase in aerobic metabolism and a decrease in the lactic acid function, which prevents the first symptoms of fatigue and forms coordination reserves as the foundation of neuromuscular performance [21].
- An outstanding enhancement of muscle strength after late puberty, which is unlikely to occur in ordinary women, would be an important requirement to become the world's top female wrestler [22].

well-developed aerobic capacity is the basis for maintaining a high level of performance [23].

- Such approaches contribute to the improvement of the adaptive capabilities of female athletes during power fitness training loads.

*Purpose of the Study* is to study the peculiarities of adaptive body changes and the level of special training in female athletes of hand-to-hand combat using power fitness programs with different structure, parameters, and means.

## Materials and Methods

### *Participants.*

We examined 36 female athletes (18-20 years old) who had been engaged in hand-to-hand combat for the last 4 years. To achieve the purpose of the

study we divided these women into two groups of 18 people in each, who used completely different power fitness training programs.

The research was approved by the Ethical Committee for Biomedical Research of the Lesya Ukrainka Volyn National University in accordance with the ethical standards of the Helsinki Declaration. The research participants gave written consent to the study in accordance with the recommendations of the Biomedical Research Ethics Committees [24]. We used diagnostic equipment of the medical center of the university for medical examination, assessment of functional parameters, biochemical control of blood serum in athletes of both groups during the study.

### *Research Design.*

Group A used the standard power fitness training program for women of this age (exercises on simulators) (table 1). Group B used well-known exercises with their own body weight with a complete change of kinematic and dynamic characteristics of the technique during 3 months of training (table 1).

Table 1 presents the most commonly used group training programs for women of this age in power fitness [9]. Thus, the athletes of group B used the training program B during 3 months of research. This program consisted of well-known exercises with own body weight, but with some peculiarities concerning kinematic (body position in space), dynamic (duration of muscle tension and recovery in a set), and rhythmic (range of motion, duration of concentric and eccentric phases) characteristics of the technique. Group A representatives used the training program A, which is standard in power fitness. The main set of tools of this program consists of exercises on simulators in compliance with standard training load parameters [11].

To assess the adaptive body changes in both group athletes we used methods of testing special training (the number of accurate kicks on the mannequin for 30 s) and laboratory control of blood biochemical parameters (cortisol and LDH) before and after training load during 3 months. Venous blood sampling was performed by a paramedic before and after training at the beginning and end of 3 months of studies in compliance with all standards [25]. The activity of lactate dehydrogenase (LDH) in the blood serum of women was determined by kinetic method on the equipment of the company «High Technology Inc» (USA) with a set of reagents PRESTIGE 24i LQ LDH (Poland). The concentration of cortisol in the blood serum was determined by enzyme-linked immunosorbent assay, using a set of steroids ELISA on the equipment of the company «Alcor Bio».

### *Statistical Analysis.*

Statistical analysis of the study results was performed using the software package IBM \* SPSS

**Table 1.** Power fitness training programs used by athletes during the study

Structural components	Training program A	Training program B
A set of means	Athletes use mainly exercises on simulators; exercise technique meets the generally accepted requirements in power fitness; no more than 2 muscle groups are involved during one exercise.	Athletes use well-known exercises with own body weight with full change of kinematic, dynamic and rhythmic characteristics of the technique; about 5-6 additional muscle groups are involved during one exercise
Training load parameters	The training lasts 90 minutes; the working weight of the load is 35-50% of 1RM; the duration of the set is about 90 seconds; rest between sets ranges within 60 s; exercises are performed with full amplitude; 3-4 sets per exercise; the number of repetitions in a set is 28-30; the total number of exercises during one training is 7-8	The training lasts 45 minutes; the set lasts until the working muscles are completely tired (performance technique deteriorates); duration of rest between sets is 30 s; the concentric phase duration is 3 s and the eccentric - 6 s; partial amplitude (85% of max) is used during exercises; intermuscular coordination is additionally activated in the concentric phase; the number of exercises in one training is not more than 6; the number of sets per exercise is 4-5.
Mechanism of correction	In most cases, it is preferable to change the projectile working mass (increase by 10-15%) and the sequence and variability of using training exercises. The speed of performing exercise is changed very rarely.	The duration of the eccentric phase increases (9-11 s) to enlarge muscle tension; the technique of performing the exercise changes due to the amplitude and position of the body in space, and changes in the level of intermuscular coordination; there is a decrease in the duration of rest intervals between sets. The level of exercise complexity and their variability is constantly changing.

Note: 1RM - one-repetition maximum.

\* Statistics 23 (StatSoftInc., USA). Descriptive statistics methods were used to calculate the arithmetic mean and the error of the mean. The non-parametric Wilcoxon test was used to assess the reliability of paired differences, and Friedman's ANOVA was used to analyze repeated measurements [26].

## Results

Table 2 presents the results special training indicators (the number of accurate kicks on the mannequin for 30 s) in female athletes of both groups during 3 months of using the proposed power fitness training programs.

The results of special training (the number of accurate kicks on the mannequin for 30 s) increased by 10.4% ( $p < 0.05$ ) in group B female athletes, who used well-known exercises in fitness with their own body weight with a complete change of kinematic and dynamic characteristics of the technique during 3 months of training. At the same time, group A athletes showed positive dynamics in special training by 2.2% although they used the standard power fitness training program (exercises on simulators). The studied indicator was compared to initial data. The obtained results indicate an increase in adaptation reserves and the level of strength endurance in female athletes of group B. These adaptation processes occur due to the increase of intramuscular and intermuscular coordination.

The results of laboratory control of cortisol concentration and LDH activity in the blood serum of both group athletes allowed to determine the

nature of adaptive-compensatory responses to stress stimuli in given conditions of muscular activity during all stages of the study (Fig. 1, Fig. 2).

The changes in the activity of LDH in the blood serum of group A athletes in response to physical stimuli showed almost identical growth of 8.2-8.4% ( $p < 0.05$ ) at all stages of the study. This fact indicates the lack of increased body functionality in these conditions of muscular activity and indicates the need to adjust the training program. However, we observed an increase in basal level of this enzyme by 12.4% ( $p < 0.05$ ) in group B athletes due to the lack of significant increase in LDH activity in response to training load at the end of the study. The obtained changes indicated the growing level of resistance in group B participants to this stress stimulus and their positive adaptive body changes.

Figure 2 graphically shows the average group values of cortisol in the blood serum of both group participants at rest and after training load using the proposed power fitness training programs for 3 months.

The results obtained at the beginning of the study showed that the concentration of cortisol in the blood serum of group A participants increased after training by 57.9% ( $p < 0.05$ ) compared with rest. At the same time, the concentration of this steroid hormone in the blood serum of group B athletes increased by 80.4% ( $p < 0.05$ ). The difference can be explained by the fact that using a set of exercises with your own body weight requires the inclusion of many additional muscle groups simultaneously, which demands significant energy expenditure to

**Table 2.** The number of accurate kicks on the mannequin for 30 s performed by both group athletes during the study, n = 36

Control exercises	Group	Observation period, months			$\chi^2$ , p df=2
		Initial data	After 45 days of training	After 90 days of training	
Front kick	A	10.68±0.22	10.80±0.23 Z=-1.1; p>0.05	10.83±0.19 Z=-0.3; p>0.05	$\chi^2=2.2$ p>0.05
	B	10.57±0.18	10.98±0.19* Z=-2.4; p<0.05	11.81±0.26* Z=-3.4; p<0.001	$\chi^2=22.6$ p<0.000
Side kick	A	13.95±0.21	14.18±0.19 Z=-1.4; p>0.05	14.21±0.18 Z=-0.4; p>0.05	$\chi^2=4.9$ p>0.05
	B	13.83±0.17	14.29±0.19* Z=-2.2; p<0.05	14.85±0.22* Z=-2.8; p<0.005	$\chi^2=15.2$ p<0.001
Reverse side kick	A	12.30±0.17	12.56±0.16 Z=-1.7; p>0.05	12.71±0.15 Z=-1.5; p>0.05	$\chi^2=9.1$ p<0.009
	B	12.38±0.14	12.94±0.17* Z=-2.8; p<0.005	13.84±0.12* Z=-3.2; p<0.001	$\chi^2=27.4$ p<0.000
Roundhouse kick	A	13.54±0.17	13.82±0.13 Z=-1.7; p>0.05	13.88±0.11 Z=-0.7; p>0.05	$\chi^2=6.1$ p<0.04
	B	13.61±0.16	13.95±0.14* Z=-2.3; p<0.05	15.15±0.16* Z=-3.9; p<0.000	$\chi^2=31.7$ p<0.000

Note: \* the difference in comparison with previous results is significant according to the Wilcoxon test (p < 0,05); df - the number of degrees of freedom; p - level of significance.

overcome the external stimulus, which increases the level of stress [9].

The results recorded after 3 months of research showed that there was an increase in cortisol level in the blood serum of group A athletes by 54.1% (p < 0.05) in response to stress stimuli. However, an increase in the concentration of this hormone in the blood serum of group B athletes was only by 5.8% compared to rest. This fact proves that increasing level of training makes the response of the endocrine system to this type of stress decrease and increases the body resistance to this kind of training [27, 28].

### Discussion

The problem of finding effective and safe ways to increase the adaptive reserves of athletes in hand-to-hand combat for their maximum implementation of tactical and technical skills in competitive activities, constantly leads to controversial discussions among specialists [2, 16].

For example, Vasilievna et al. [29] argue that strength exercises based on mixed muscle work have a targeted effect on the muscles of the arms, legs, and abs of hand-to-hand combat athletes. Serebryak et al. [30] conducted a study involving 58 hand-to-hand combat athletes. The authors have developed and approved the most effective technical and tactical schemes for building a duel with opponents. Our training program is supplemented by the

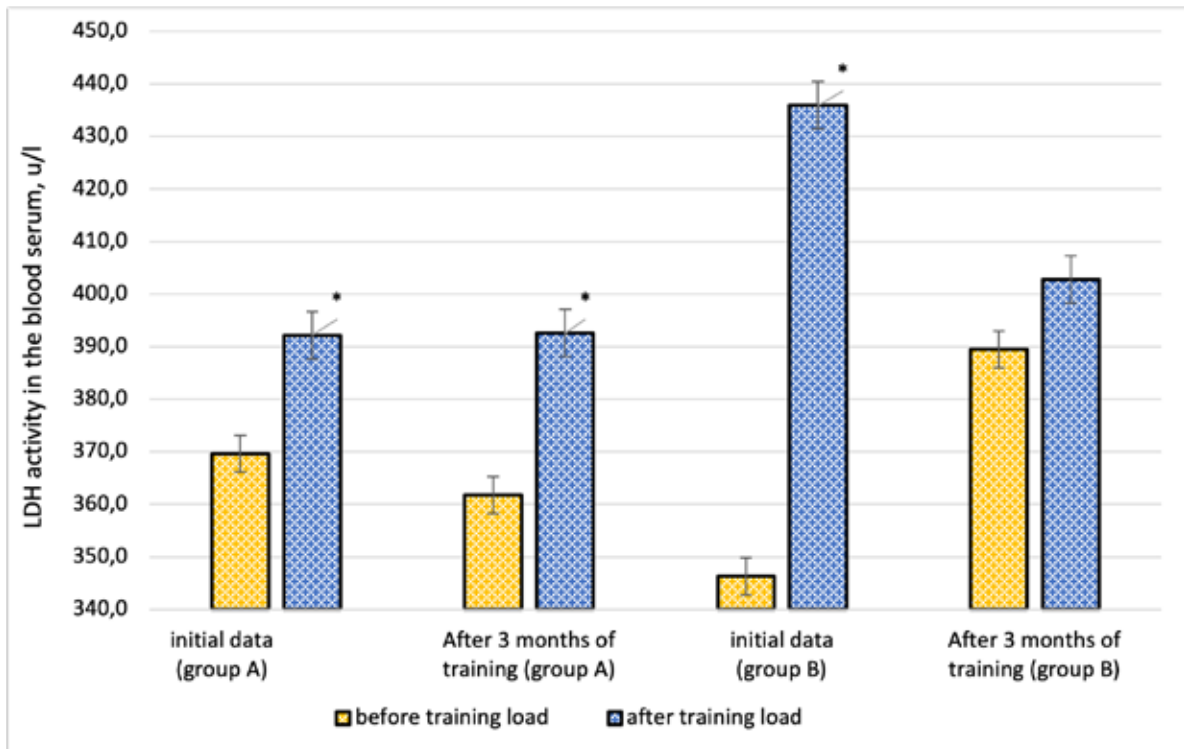
results of the analysis of biochemical parameters. In this context, our approach requires the involvement of other specialists in the training of hand-to-hand combat athletes.

The main concern is the need to optimize loads in the process of special power training in hand-to-hand combat and especially among women, which will increase the level of functional body capabilities in the shortest possible time. One of the main aspects of improving the control system of training loads, which scientists have been paying attention to in recent years, is the systematic use of blood biochemical indicators to assess adaptation processes [3, 13, 17, 31].

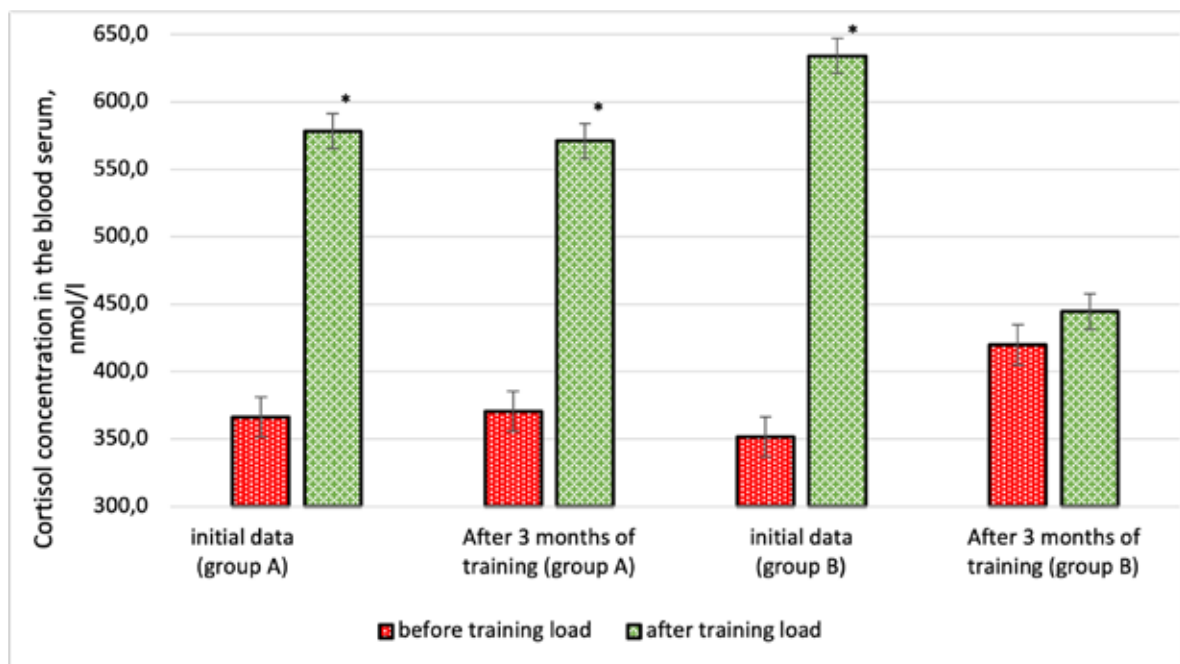
Our research determined that using only power fitness training program, consisting of exercises with their own body weight and a complete change of standard kinematic and dynamic characteristics of equipment, helped hand-to-hand combat female athletes to improve special training results. The obtained data confirmed the results of research in power fitness using the same training loads for women of this age group [9, 32, 33].

In this context, study by Bujak et al. is a good addition. [34]. The authors argue that hand-to-hand combat requires different bioenergetic potential and anthropometric profile of athletes.

The changes in cortisol concentration and LDH activity in the blood serum of hand-to-hand



**Fig. 1.** Change in LDH activity in the blood serum of group A and B female athletes during the research, n = 36. Note: \* - p < 0.05, compared to the indicators before training load.



**Fig. 2.** Change in the concentration of cortisol in the blood serum of group A and B female athletes during the research, n = 36. Note: \* - p < 0.05, compared to the indicators before training load.

combat female athlete using power fitness training programs do not coincide with the results presented in the available scientific literature [27, 28, 35]. At the same time, we have not found data on using biochemical parameters of blood serum (cortisol and LDH) in hand-to-hand combat athletes to assess changes in the adaptive body reserves in terms of

muscular activity of power orientation.

### Conclusion

The special training results increased by 10.4% (p < 0.05) on average in female athletes of hand-to-hand combat, who used power training programs, consisting of exercises with their own body weight

with a complete change of kinematic and dynamic characteristics during 3 months of research. At the same time, the studied indicator increased by only 2.2% compared to initial level in female athletes who used the standard power fitness training program for women of this age (exercises on simulators).

The increase in cortisol concentration in the blood serum of group B athletes, recorded at the end of the study in response to physical stimuli, was almost 10 times lower compared to the results of group A athletes. There was an increase in LDH activity in the blood serum by 19.5% ( $p < 0.05$ ), especially its initial level, in group B representatives during the entire study period.

Determining the most effective power fitness training program for special training of female athletes in hand-to-hand combat will help to increase their adaptive body reserves and their level of fitness in the shortest possible time by using different in structure and parameters training load.

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### Conflict of interest

No potential conflict of interest that is of any relevance to this study was reported by the authors.

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# The impact of existing and modify wrestling shoes on foot posture deformities in 12-13 years old athletes

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## Abstract

**Background and Study Aim** In the early years when sports footwear became compulsory, the importance of shoe design was not considered in terms of athletes' health. Since the early years of wrestling shoe use, these gears have been manufactured according to the rules of competition, and modifications have been very limited. In this regard, this study aims to determine the effect of existing wrestling shoes on foot deformation.

**Material and Methods** The study was carried out with the participation of 108 young male athletes who had the same training on the same ground for three years in the Wrestling Training Center. The athletes were divided into two groups, an experimental and a control group. While the control group wore wrestling shoes produced by widely used brands, the experimental group wore newly designed wrestling shoes. Foot arch values and images of both groups were determined using a podoscope device at the beginning and end of the study. The evaluations were made according to the Staheli arch index.

**Results** The results of the statistical analysis revealed that differences were found in the footprint measurement values of the control group. It was determined that this difference in the footprints was greater among the freestyle wrestlers. The decrease in the averages between the first and second measurement values of the group using the newly designed wrestling shoes was found to be highly positive and in a linear direction. Also, it was determined that the pain score values of the control group were higher than the scores of the experimental group after training.

**Conclusions** The results revealed that there were deformations in the feet of the control group wrestlers wearing available wrestling shoes. It was observed that freestyle wrestling athletes had more deformation than Greco-Roman style wrestlers, and leg pains were more prevalent after training and competitions. Based on these results, it was concluded that the design of wrestling shoes produced with today's technology needs to be redesigned.

**Keywords:** wrestling, athlete health, sports shoes, wrestling shoes, flatfoot, leg pain

## Introduction

Wrestling athletes competed for bare feet on the dirt floor at the 1896 Athens First Modern Olympics, while in London in 1908, they competed for the first time on thick, soft cushions with leather shoes tightly wrapped around the ankles on their feet [1]. These shoes with ankle support worn at the 1908 London Olympics have been used to this day, maintaining similar characteristics without much change. As a rule, wrestling shoes must have no heels and wrap the foot in tight laces [2].

The physical structures constructed by sports branches are not the same in terms of posture and anthropometric characteristics because their movement angles and requirements are different [3]. Studies report that the postural structures and necessities of sports branches are distinct from

each other [4]. As a performance sport, wrestling requires physical health and balance in addition to characteristics such as physiological, psychological, technical, tactical, strength, and agility traits. Of these characteristics, balance has a special place in wrestling. Foot posture plays an important role in maintaining balance [1].

Many studies report that the existing wrestling shoes cause flatfoot deformity [1, 5, 6]. Flatfoot is the straightening or disappearing of one of the longitudinal or transverse foot arches at the sole. This condition obstructs the facility of springing and prevents normal movement during walking and running. Flatfoot is also defined as "deformity caused by decreased height or complete collapse of the medial longitudinal arch of the foot" [7]. Pes planus is defined as the decreased or complete loss of medial longitudinal arch (MLA) height of the foot. In pes planus, the head of the talus is replaced planar from the medial and navicular bone. This relocation

leads to loss of height in the MLA by stretching the arch-formed tendon of the tibialis posterior muscle [8]. When the medial longitudinal arch decreases, heel eversion occurs due to the overpronation of the foot compared to normal foot, and by shifting the body weight inwards, pressure is exerted on the MLA, and therefore, the tension is created on the MLA [9]. If the medial longitudinal arch undergoes structural or functional deterioration or disappears completely, the ability of the foot to dampen the ground reaction force decreases, its effect in keeping balance decreases, difficulties in walking emerge, and the endurance of the muscles decreases [10]. In a survey study conducted by Prvulović et al. for years between 2002 and 2018, it was determined that the most common deformity among foot deformations in athletes with different sports backgrounds was the flatfoot disorder. In addition, in this study, they found that athletes who had flatfeet achieved lower results when performing motor tasks compared to the individuals with normal foot structure in terms of time and reaction speed [11]. As can be seen from these studies, it is very important for athletes' health and performance to investigate the reasons why athletes develop flatfeet and to find solutions.

It is known that the population of athletes with flatfeet is high in the wrestling branch and that wrestling shoes are the main factors that cause this upsurge [1, 5, 6]. In this context, the need for a new wrestling shoe design contributes to the significance of this study.

The number of studies investigating the foot structure of athletes is very limited. Therefore, the effects of wrestling shoes on foot structure have not been clearly understood yet. As a result, this study may help determine the effects of new wrestling shoes on the foot structure of athletes after wrestling in these new shoes. In other words, this study aims to redesign wrestling shoes, which are thought to disrupt the foot structure of wrestlers, and to investigate their effects on athletes.

## **Materials and Methods**

### *Participants.*

A total of 108 male volunteering athletes, aged 12-13, who were novice wrestlers participated in the study. The participants were athletes of the Wrestling Training Center (in Turkey), where young wrestlers are enrolled through selection and are given boarding school education. Of the participants, 51.9% were 12 years old, and 48.1 % were 13 years old. In terms of their wrestling styles, 50% of the participants were competing in freestyle, and 50% were Greco-Roman-style wrestlers. Students who exercised regularly at least three days a week and whose foot sole values were normal according to the Staheli index [12, 13, 14] were selected for the research. The participants were informed about

the research before the investigations. The athlete candidates were divided into an experimental and a control group with 54 participants in each group. The control group wore the two most used brands of wrestling shoes that were available on the market. On the other hand, the experimental group wore the newly manufactured wrestling shoes. Many changes were made in these new shoes. In the present wrestling shoes, which were found to cause foot deformity and balance disorders in previous studies, the outer sole, inner sole, heel part, shoe surface, laces and ankle parts of the boot were revised. Both groups underwent the same training on the same ground. In the three-year study, the weekly training program of the athletes was renewed every six months. The six-month weekly training program of the athletes was prepared. To assess the deformations caused by the shoes, the foot soles were imaged using a podoscope at the beginning and end of the study. Informed consent was obtained from all participants. The research was conducted in accordance with the ethical principles of the Helsinki Declaration. The study was approved by the Clinical Research Ethics Committee of Inonu University (2018/106).

### *Research Design.*

The study was conducted between August 2018 and June 2021. Three-year training programs for athletes were prepared in the Wrestling Training Centers (WTC) where the study was conducted. These training programs were divided into six-month periods, and the content was modified. In the weekly training program for the first six months, the athletes trained four days a week. In this phase, the adaptation of the athletes to the WTC and the development of basic motoric properties were targeted. Information about the conditions of the athletes was collected by making physical tests after the first six months. The athletes performed all their training, except sports games, in their wrestling shoes. The training was made five days a week in the second six-month period. The basic postures and grips in wrestling, as well as the teaching of ground techniques, were started at this stage. During the first six-month period of the second year, the weeks were planned as five days of training and one day of sports games. Football was played when the weather was conducive to playing football. When this was not the case, wrestling basketball was played on the mat. In the second half of the second year, more time was allocated to basic wrestling and gymnastics skills. The athletes started to play control matches among themselves. In the first six months of the third year, more time was devoted to versatile technical and tactical work. The athletes made partner drills in addition to studies with their body weight, and they worked with small weights. The number of control matches and the work on the

wrestling style (freestyle or Greco-Roman) chosen by the athlete were emphasized in this period. In the last six months of the study, the number of control matches was increased as athletes were eligible to wrestle.

Throughout the study, redesigned shoes were given to athletes whose foot size grew in the experimental group, while the control group was given wrestling shoes from existing brands.

*Data Collection.*

*Measurements of Footprints*

Faster and more accurate results were obtained in the foot sole measurements and footprint evaluation using a podoscope device (Chinesport S.P.A. Udine, Italy). In this method, the person stands still on a glass surface, and the image of the foot is reflected on the mirror underneath. This image is then recorded on the computer and the planimetric index values that are calculated with the highest sensitivity determine whether the arch of the foot is normal, cavus, or flatfoot [15]. All pre-measurement conditions such as the time between removing the shoes and starting the test, standing on the glass surface with bare feet, were the same for all participants. After the feet soles of the participants were wiped with alcohol and dried, the participants were asked to stand on the podoscope in an upright and still position distributing their body weight evenly on both feet. They were positioned with their heads upright, facing straight across. The images obtained were analyzed using the Global Postural System/PODATA software. The overall foot sole structure was evaluated employing Staheli's plantar arch index (SI). The SI index is the ratio obtained by dividing the narrowest width of the middle of the foot into the widest width of the heel area. According to this method, ratios between 0,50 and 0,70 are normal, while ratios above 0,70 are considered pes planus [12, 13]. While calculating the Staheli index  $SI=a/b$ , the measurement areas were expressed as; a: the narrowest width of the middle

of the foot, b: widest width of the heel area [12, 13, 14].

*Determination of Leg Pain Values*

In the evaluation of pain, a visual analogue scale was used to determine athletes' pain complaints, the most severe pains that occur after training or matches, pains during running, pains during squatting, and pains when climbing stairs and descending stairs. The visual analogue scale (VAS), which was used to translate some values that cannot be measured numerically into numeric values, was numbered at equal intervals from 0 to 10 on a 10 cm line. The number 0 stood for 'no pain at all,' whereas the number 10 indicated 'unbearable pain.' In this manner, the participants were asked to mark the severity of the pain they perceived [16].

*Statistical Analysis.*

The data obtained from the research group was analyzed using the SPSS 22 package program. Since the data showed normal distribution, parametric test methods were utilized. The frequency and percentage dispersions of demographic variables were calculated. Independent samples t-test was performed in pairwise comparisons of independent variables. Paired samples correlation test was used for correlation analysis, whereas paired samples t-test was utilized for the comparison of first and second measurement values. The level of statistical significance was set at  $p<0.05$  in the study.

**Results**

According to Table 1, there was no statistically significant difference between the first and second measurement values in terms of the wrestling style variable (freestyle or Greco-Roman) in the experimental group ( $p>0.05$ )

As demonstrated in Table 2, no statistical significance was found in terms of the variable of wrestling style (freestyle or Greco-Roman) in the first measurement values in the control

**Table 1.** Footprint analysis results of the experimental group by the wrestling style variable

Wrestling Style		n	Mean	SD	t	p
1 <sup>st</sup> Measurement	Freestyle	27	0.61	0.048	-0.333	0.741
	Greco-Roman	27	0.62	0.042		
2 <sup>nd</sup> Measurement	Freestyle	27	0.60	0.046	1.195	0.237
	Greco-Roman	27	0.59	0.040		

**Table 2.** Footprint analysis results of the control group by the wrestling style variable

Wrestling Style		n	Mean	SD	t	p
1 <sup>st</sup> Measurement	Freestyle	27	0.63	0.040	1.575	0.121
	Greco-Roman	27	0.61	0.050		
2 <sup>nd</sup> Measurement	Freestyle	27	0.71	0.133	2.128	0.038*
	Greco-Roman	27	0.65	0.085		

\* $p<0.05$

group ( $p>0.05$ ). However, a statistically significant difference was determined between the second measurement values ( $p<0.05$ ).

The means of the first and second Staheli Index values of the experimental group were presented in Table 3. As seen in these findings, there was a decrease in the mean values of the second measurement.

The correlation coefficient between the first and second measurement values of the experimental group were presented in Table 4. There was a statistically significant relationship between first and second measurement values of the experimental group ( $p<0.05$ ). The decrease in averages between first and second measurement values was in a strong positive linear direction.

According to Table 5, it was determined that the difference obtained from the comparison between the first and second measurement values was statistically significant in the experimental group ( $p<0.05$ ).

The means of the first and second Staheli Index

values of the control group were presented in Table 6. It was seen that there was an increase in the averages of the second measurement values.

Table 7 indicates that the correlation coefficient between the first and second measurement values in the control group is  $r=0.826$ , and it is statistically significant ( $p<0.05$ ). The increase in averages between first and second measurement values was in a strong positive linear direction.

As demonstrated in Table 8, the difference obtained from the statistical comparison between the first and second measurement values of the control group was determined to be statistically significant ( $p<0.05$ ).

As Table 9 indicates, there was a statistically significant difference in pain scale values between the experimental and control groups in the research group in favor of the experimental group ( $p<0.05$ ).

As presented in Table 10, it was determined that there was a statistically significant difference in pain scale values in terms of the freestyle and

**Table 3.** Descriptive statistics of measurement values of the experimental group (Paired Samples Statistics)

Variables	n	Mean	SD	Std. Error Mean
1 <sup>st</sup> Measurements	54	0.62	0.045	0.006
2 <sup>nd</sup> Measurements	54	0.60	0.043	0.005

**Table 4.** Correlation analysis between measurement values of the experimental group (Paired Samples Correlations)

Variables	n	r	p
1 <sup>st</sup> Measurement & 2 <sup>nd</sup> Measurement	54	0.789	0.000*

\* $p<0.05$

**Table 5.** The analysis results between the 1st and 2nd measurement values of the experimental group (Paired Samples test)

Experimental group	Paired Differences						t	df	p
	Mean	SD	Std. Error Mean	95% Confidence Interval of the Difference					
				Lower	Upper				
1 <sup>st</sup> Measurement-2 <sup>nd</sup> Measurement	0.01611	0.02864	0.00390	0.00829	0.02393	4.133	53	0.000*	

\* $p<0.05$

**Table 6.** Descriptive statistics of measurement values of the control group (Paired Samples Statistics)

Variables	Mean	n	SD	Std. Error Mean
1. Measurement	0.62	54	0.046	0.006
2. Measurement	0.68	54	0.115	0.015

**Table 7.** Correlation analysis between measurement values of the control group (Paired Samples Correlations)

Variables	n	r	p
1 <sup>st</sup> Measurement & 2 <sup>nd</sup> Measurement	54	0.826	0.000*

\* $p<0.05$

**Table 8.** The analysis results between the 1st and 2nd measurement values of the control group (Paired Samples test)

Control group	Paired Differences					t	df	p
	Mean	SD	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
1 <sup>st</sup> Measurement-2 <sup>nd</sup> Measurement	-0.06481	0.08149	0.01109	-0.08706	-0.04257	-5.845	53	0.000*

\*p<0.05

**Table 9.** Pain scale analysis of the study group (Experimental-Control)

Groups		n	Mean	SD	t	p
Pain Scale	Experimental	54	0.2222	0.63444	-4.158	0.000*
	Control	54	1.5741	2.30342		

\*p<0.05

**Table 10.** Pain scale analysis results of the study group according to the wrestling style variable

Wrestling style		n	Mean	SD	t	p
Pain Scale	Freestyle	54	1.7596	1.9814	2.431	0.005*
	Greco-Roman	54	0.6667	1.61362		

\*p<0.05

Greco-Roman style wrestling status of the study group (p<0.05). Accordingly, the pain scale values of the freestyle wrestling athletes were higher.

## Discussion

Approximately half of the athletes in the study were 12 years old (51.9%), while the other half was 13 years old (48.1%). The participants were selected from the athletes who qualified to study boarding at Wrestling Training Centers. Of the participants, 50% were freestyle wrestlers, and 50% were Greco-Roman wrestlers. The participants applied to the same training program for three years.

No difference was found between the first and last measurements in the footprint images of the participants. However, differences were found in the footprint measurement values of the control group. It was determined that this difference in the footprints was greater among the freestyle wrestlers. In the relevant literature, the findings of the study by Aydog et al. [17] are in parallel with the findings of our present study. In addition, the results of our study that indicate a significant relationship between freestyle and Greco-Roman wrestling styles and the pes planus condition are in line with the research by Aak et al. [1] and Tařkiran et al. [18]. The reason that flatfoot deformity is more prevalent in freestyle wrestlers than in Greco-Roman style might be because freestyle wrestlers bend forward more, stand with their feet sideways apart for balance, and they pull and push their opponent forward, backward, and sideways. Owing to the shock-absorbing feature of the shoe sponge, the

contact surface of the sole surface with the mat may be more than desired. This may lead us to consider that flatfoot deformity has a higher incidence among freestyle wrestlers because of this condition. Furthermore, the fact that the surrounding of the shoe is overly wrapped prevents the movement of the Achilles tendon. The failure of the Achilles tendon to stretch supports the idea that there is a predisposition effect on the higher incidence of flatfoot deformity among freestyle wrestlers.

The decrease in the averages between the first and second measurement values of the group using the newly designed wrestling shoes was found to be highly positive and in a linear direction. This finding demonstrates that the manufactured shoes brought the foot sole values of the athletes to the ideal norms over time. On the other hand, the mean values of the second measurements of the control group who were using pre-existing wrestling shoes increased. The increase in the means between the first and second measurements was highly positive and in a linear direction. Considering this finding, it can be said that if wrestlers continue to use existing wrestling shoes, there will be an increase in foot sole deformation, and the existing shoes will cause permanent flatfoot problems. As a result of their pes planus scan in 685 athletes who wrestled regularly, Tařkiran et al. [19] determined that as the year of doing sports increased, the incidence of developing pes planus in freestyle wrestlers (25.7% pes planus cases) was higher than Greco-Roman wrestlers (15.6% pes planus cases). This data indicates that the rate of developing flatfoot increases in parallel

to the wrestling age of athletes. The findings of our research are in line with the studies by Taşkıran et al. [18]. In their study that supports the findings in this current research, Wojtys et al. [20] stated that intensive training made at early ages has effects on the posture.

In the present study, it was determined that the pain score values of the control group were higher than the scores of the experimental group after training. In the control group, the pain score values of freestyle wrestlers were also found to be higher when the wrestling style is considered. People who have flatfeet cannot absorb shock and spread it to their feet due to their lack of natural foot arches. The forces applied to the soles of the feet and the upper part of the body cause chain reactions to all body connections, especially in the spine and lumbar spine [21]. This condition leads to pain in individuals with flatfeet after activities such as standing [22], walking, and running [7]. Violante et al. [23] and Oskay and Yakut [24] concluded that there was a positive relationship between individuals with flatfeet and lumbar pain. Similarly, Kaufman et al. [25] maintained that pes planus triggered pain sensation in feet, stiffness, imbalance

in feet muscles, the tension in ligaments, rapid exhaustion while walking, and most importantly, stress fractures. As these results demonstrate, flatfeet cause many posture disorders.

### Conclusions

In light of the findings of this study, it is possible to say that wrestling shoes need to be redesigned. Pes planus deformity should be considered in sports branches in the selection of athletes and the processes of sporting rehabilitation. In the future, research on athletes' success rates in tournaments after deformity prevention practices and the impact and solution of athlete equipment on athlete health can be investigated to contribute to the literature.

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### Conflict of interest

The authors state that there is no conflict of interest

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## Bibliometric analysis of harassment and bullying in sport

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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** This study aims to chart the trend of publications in the Scopus database and the Web of Science as well as the global evolution of harassment and bullying in sports.

**Material and Methods** ScientoPy and VOSviewer software were used in this study to analyze the number of publications, well-known research topics, proactive authors, author keywords, preferred sources, and institutional data. This study uses data reconciliation with 1, 883 different items from the Scopus database and the Web of Science. An increasing trend in sports nutrition research was found using the Scopus and WoS databases.

**Results** This field has grown significantly since 2015. In addition, the percentage of documents published in the last two years (2020 to 2021) shows that 22.40% were published on WoS and 22.04% on Scopus. The five keywords that are trending topics between 2020 and 2021 are "Sports", "Racism", "Race", "Sexual Harassment", and "Gender". Meanwhile, the keywords with the highest total link strength were "sports" (244), "racism" (169), "bullying" (165), "adolescents" (161), and "physical activity" (150). The University of Toronto, Canada, became the most productive institution with 22 publications.

**Conclusions** The most prestigious institutes and researchers in the field of harassment and bullying research in sports have been recognized, along with key research areas, keywords, and related papers. The study also offers potential readers and researchers a global perspective on the hottest issues in harassment and bullying in sport today. In addition, it provides various analyses to assist in the organization of data for the development of harassment and bullying research theories and methodologies in strong sports.

**Keywords:** harassment, bullying, bibliometric, Scopus, Web of Science

### Introduction

Harassment and oppression are unacceptable behaviors that can be carried out by individuals or groups against other individuals or groups that tend to harm them psychologically, socially, or economically. Bullying in sports, both by coaches and athletes, has recently received public attention [1]. The empirical literature on sexual violence and harassment in coach-athlete interactions serves as the sole basis for the identification of risk variables for athlete maltreatment in sport [2]. When trying to implement bullying and harassment management tools in sports, it can be difficult due to behaviors of sports leaders and even athletes themselves, such as ignoring, not responding to, and resisting bullying and harassment prevention [3]. Body contact, such as hitting the victim or damaging clothing or other property, can be considered physical intimidation [4].

A number of qualitative studies that have been conducted support the idea that bullying and

harassment, which may be difficult to identify, dominate in sports [5]. Several studies have also been conducted on bullying in sports, but 30% of young people say they have been bullied, according to True Sport [6, 7]. These studies also claim that antisocial behavior that manifests as aggression or violence in sports is often planned and purposeful [8]. In addition, because players are traumatized by the increasing prevalence of violence in sports, it may be difficult to spot bullying and harassment [9]. Bullying often discourages people from participating in sports, whereas hazing is done to increase commitment and be seen as a team member [4]. Bullying and hazing are both types of moral detachment that encourage and support antisocial behavior rather than prosocial behavior [4, 10, 11].

Harassment and abuse in sport is the result of an imbalance of power [12, 13], which is made possible by an organizational culture that belittles, denies, fails to stop, or even implicitly tolerates the problem [14]. The only large-scale study currently available is from the UK, where 75% of cases of psychological abuse are documented. These findings raise concerns that this may be the most important child sports

protection issue [15, 16]. Athletes report that they are ignored or denied support and attention, and are subjected to verbal abuse, yelling, scapegoating, rejection, exclusion, and threatening behavior [16, 17, 18, 19, 20].

Several bibliometric studies have been conducted in various fields, including: bullying among adolescents [21], cyberbullying [22], sexual harassment in the workplace [23], cyber bullying and education [24], bullying and harassment [25], cyber bullying and bullying [26], verbal bullying at school [27], adult bully syndrome [28], bullying in children [29], aspects of bullying and psychosocial [30], and bullying of students with disabilities in physical education [31].

The current study seeks to: 1) identify significant key sources and institutions in the area of harassment and bullying in sports; 2) conduct author keyword analysis and influential sports harassment and bullying research; and 3) identify publishing growth and important research areas of harassment and bullying in the most prominent sports. By providing potential readers and researchers with a summary of studies conducted on the quality of this harassment and bullying component, the authors hope this article will contribute to advancing understanding of current trends in harassment and bullying research in sports.

## Methodology

### *Data Source*

This study combines metadata from two well-known databases, Scopus and WoS, to analyze the growth and current trends in harassment and bullying research in sports. As such, it highlights the value of reviews in detecting problems and points the way forward for scientific research. The research objectives, which include evaluating the effects of publications, fields of study, authors, sources, and institutions by country based on the selected database, are also relevant to this study.

### *Method of Study*

The software framework used to organize the most significant research subjects, authors, countries, and related publications is called ScientoPy. ScientoPY is a free and open-source software built on top of Python that can eliminate bias in certain articles [32]. The following is possible with the ScientoPy script: Gaining access to the Clarivate Web of Science and Scopus databases is the first step. To account for the incoming data set, ScientoPy automatically creates preprocessing steps, including the number of articles per database both before and after the duplicate elimination filter is used [33]. A bibliometric review has grown in popularity as a result of the large number of published studies in almost all fields of knowledge [34]. Steps two through eight involve finding and

removing duplicate documents; sorting publications by document type; creating a graph showing the history of the most popular topics; creating a graph showing the history of selected items in a topic; and finding popular topics by looking at the top of the average growth rate (AGR), and calculate the h-index for the author and country. Building a system for analyzing research in the literature and finding publication patterns and trends has proven reliable with bibliometric analysis [35].

On August 14, 2022, institutional subscriptions were used to access the Scopus and WoS databases to obtain metadata for the current study. The data retrieval process begins with identifying the right keywords, related data, and the unique purpose of the analysis. In bibliometric analysis, the number of metadata requirements varies greatly. The minimum and maximum metadata standards that can be evaluated, as well as the number of metadata standards for bibliometric analysis, are not stated [36]. The metadata related to harassment and bullying in sports was collected using keywords based on: TITLE-ABS-KEY (“sport\*” OR “competitive game” OR “physical activity” OR “pastime” AND “bully\*” OR “racial bullying” OR “ethnic bullying” OR “racis\*” OR “harassment” OR “pester\*” OR “annoyance” OR “nuisance” OR “persecut\*” OR “bedevilment”). found as many as 1, 895 documents on Scopus and 1, 585 documents on the Web of Science (WoS). Data was collected in both databases on August 23, 2022. Data collection is only carried out on article-type documents.

### *Data Analysis*

The following types of documents are currently used by ScientoPy to process data: 1) papers presented at conferences; 2) articles; 3) reviews; and 4) papers [32]. Books, book series, and letters are among the documents left behind from this investigation. In addition, ScientoPy normalizes author names for metadata retrieved from the Scopus database by replacing them with semicolons, periods, commas, and special characters for metadata retrieved from both databases, and eliminates duplicate samples with the same title and author during the preprocessing stage [37].

Table 1 displays a preprocessed summary of all loaded documents for each database along with entries for which duplicates were removed. According to Table 1, the ScientoPy preprocessing script places the WoS document in front of the Scopus document; when duplication is removed, there are more documents from the WoS database than there are from Scopus.

## Results

The growth of harassment and bullying publications in sports across both databases is depicted in Figure 1. This shows the remarkable

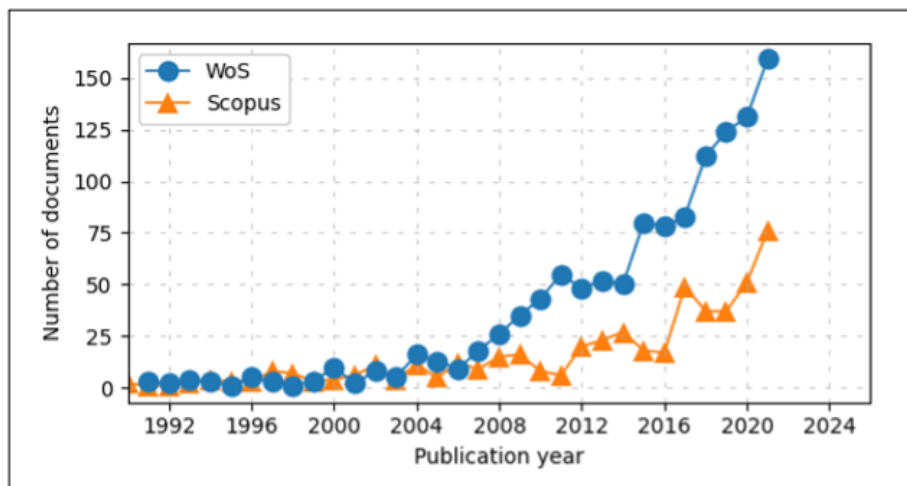
direction in which this field has grown significantly since 2015. In addition, the percentage of documents published in the last two years (2020 to 2021) shows that 22.40% were published on WoS and 22.04% on Scopus. The publication fluctuations for Scopus and the WoS database are depicted in Figure 1. Scopus has 586 documents, while WoS has 1,297 documents. This encourages researchers to continue to invest in ways of thinking and perspectives related to the study of harassment and bullying in sports, so that thinkers, researchers, and practitioners of physical education and sports can have an open dialogue. With 80 documents on Scopus and 213 documents on WoS published, 2021 was the most productive year for publishing papers related to harassment and bullying in sports. The WoS and Scopus databases had AGR, ADY, and PDLY, respectively (WoS, 13.05; Scopus, 22.05); (WoS, 203; Scopus, 61.05); and (WoS, 22.04, Scopus, 22.00 respectively). WoS also has an H-index greater than Scopus, with a value of 90 for

WoS and 36 for Scopus.

Based on their particular institution or affiliation, the authors are mentioned in the publication. Researchers can choose study locations and form future collaborations thanks to their knowledge of which institutions are best represented on the topic of harassment and bullying in sports studies. Figure 2 shows a bar graph of the top ten countries where studies on sports harassment and bullying have been published. According to Figure 2, the United States had the most published articles (635 publications). With 280 publications, the United Kingdom ranks second. Australia is in third place with 144 articles, and Canada is in fourth place with 138 articles. Only these four countries have published more than 100 articles. Germany became the country that contributed the most manuscripts during 2020 to 2021, with a total of 42% of all articles published in 2020 to 2021. Followed by Spain with a total of 40% in the second position and Brazil with a total of 35%

**Table 1.** Pre processing brief

Info	Number	Percentage
Loaded papers	2698	
Omitted papers by document type	0	0.0%
Total papers after omitted papers removed	2698	
Loaded papers from WoS	1304	48.3%
Loaded papers from Scopus	1394	51.7%
Duplicated removal results:		
Duplicated papers found	815	30.2%
Removed duplicated papers from WoS	7	0.5%
Removed duplicated papers from Scopus	808	58.0%
Duplicated documents with different cited by	508	62.3%
Total papers after rem. dupl.	1883	
Papers from WoS	1297	68.9%
Papers from Scopus	586	31.1%



**Figure 1.** The publication growth of harassment and bullying in sport on Scopus and WoS databases

Source: (Results of ScientoPy software analysis up to August 23, 2022)

in the third position.

For each country, Figure 3 shows how the total strength of co-authorship links with other countries will be calculated. The country with the greatest total link strength will be selected. The minimum number of 5 documents owned by the country and the minimum number of citations is 0.41 countries found related to studies on harassment and bullying in sports. The United States became the country with the largest total link strength, namely 138. The United States also obtained 8601 citations from 438 published documents. The total strength of links, citations, and number of documents from each subsequent country is the United Kingdom (225,

5027, 124), Canada (127, 1684, 77), Australia (127, 2040, 74), and Spain (79, 678, 56). Only those five countries have a total link strength of more than 50. The stains also describe the clusters of each country. In addition, the thickness of the line indicates that each country has a close relationship with joint research and publications. The United States is in Cluster 4, along with Australia, China, Croatia, India, and Japan. Figure 3 shows a visualization of the co-authorship network by country.

In publishing their papers, it is certain that most of the authors must provide information related to where they serve and work, so that the identity of the author's affiliation can be known. This will also

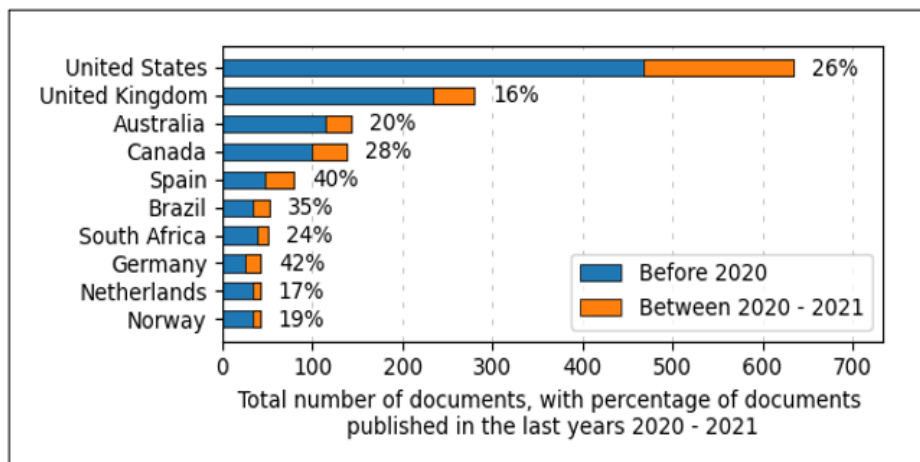


Figure 2. The top ten countries

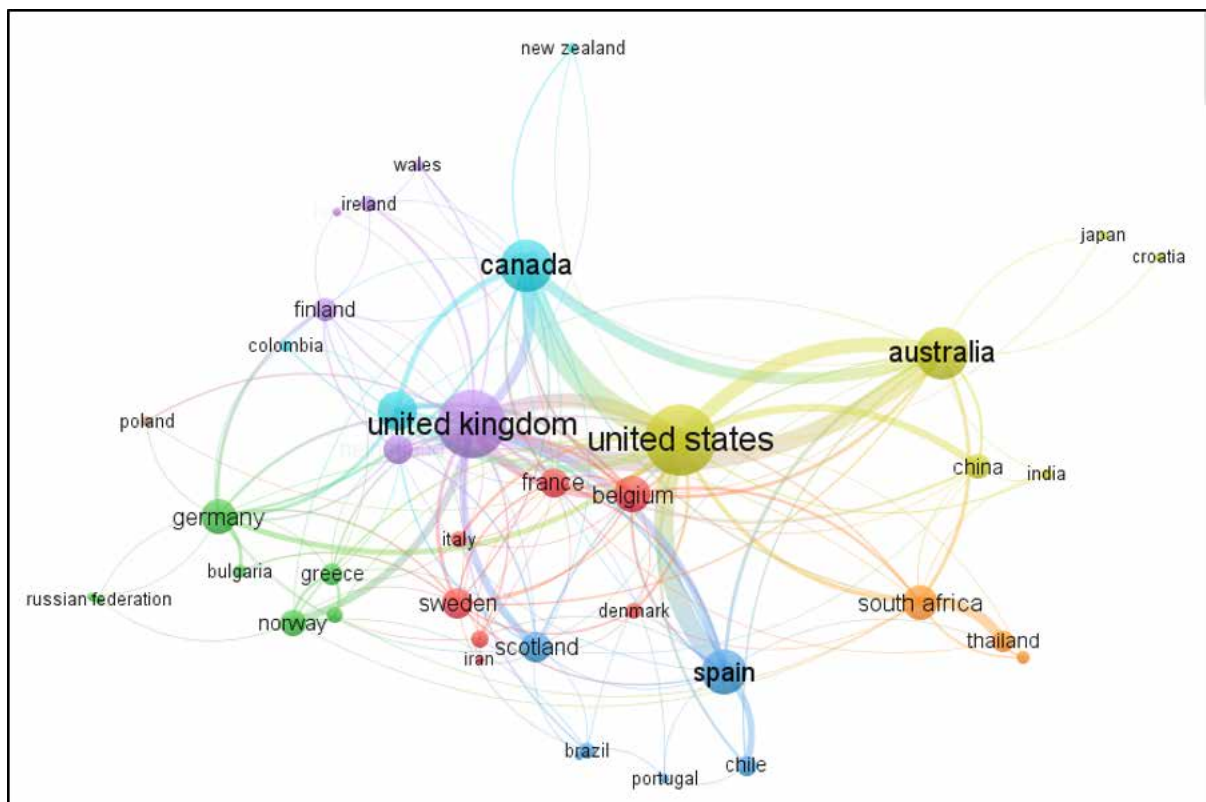


Figure 3. Total link strength co-authorship base on country

have an academic impact on the name and position of the institution in the eyes of the state, other institutions, professionals, researchers, teachers, and students. Figure 4 is a word cloud that describes the 20 most productive publishing institutions for harassment and bullying in sports. Considering Figure 4, the larger the size of the institution, the larger the number of publications. This study reveals that the University of Toronto, Canada, has 22 publications with AGR (00.05), ADY (03.05), PDLY (31.08), and H-index (11) being the most active educational institutions or institutions in publishing papers related to harassment and bullying in sports. Leeds Beckett University, United Kingdom, is ranked as the second most active university with 19 documents, AGR (-0.5), ADY (02.00), PDLY (21.01), and H-index (10). The list of names of universities, affiliates, and other institutions is shown in Figure 4.

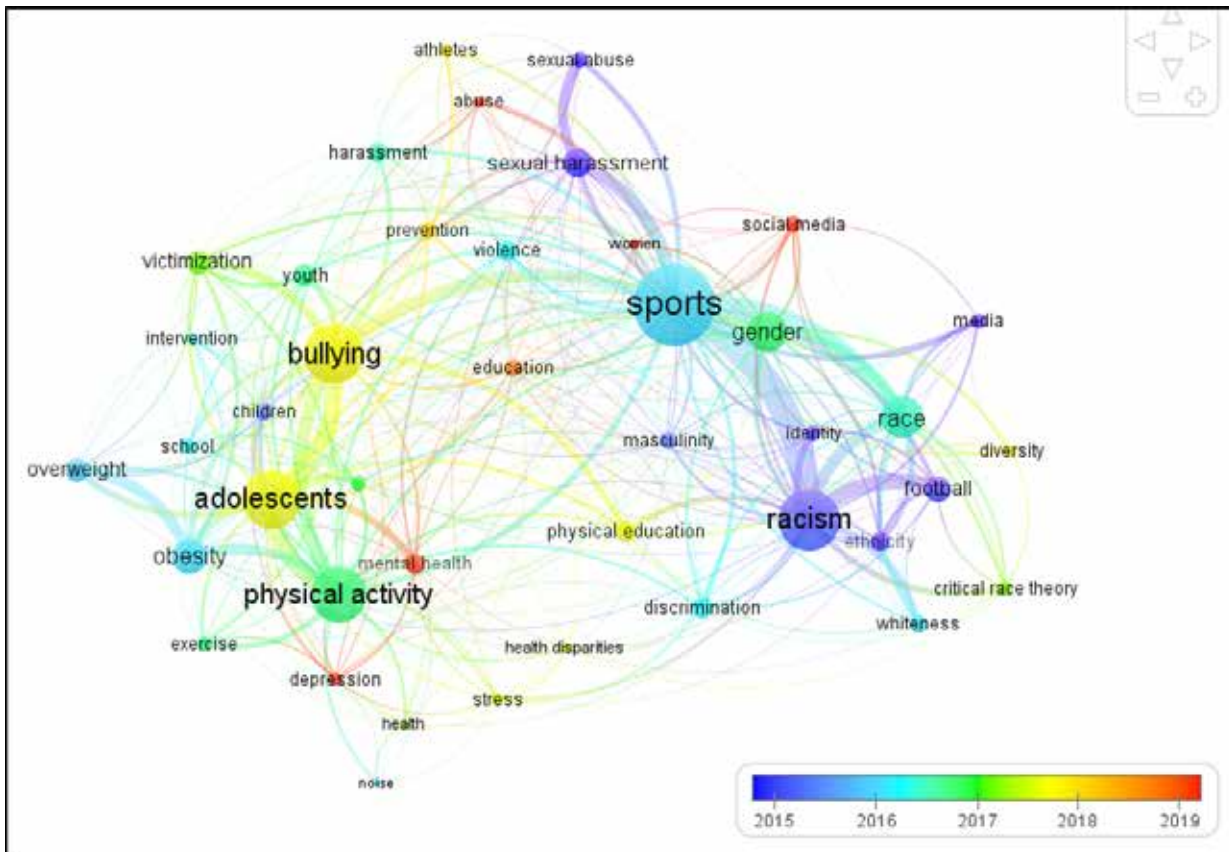
This study uses cluster mapping to determine

the co-occurrence of the authors' keywords with the aim of identifying themes or topics that are relevant to sports nutrition. The data set (a combination of Scopus and WoS metadata) was preprocessed with ScientoPy before creating a network map with VOSviewer. Furthermore, this study uses a thesaurus file to map the co-occurrence of the author's keywords. Thesaurus files are essential for combining similar terms, spelling variations, and singular or plural terms such as "sport" and "sports", "adolescents", "adolescent", and "adolescence".

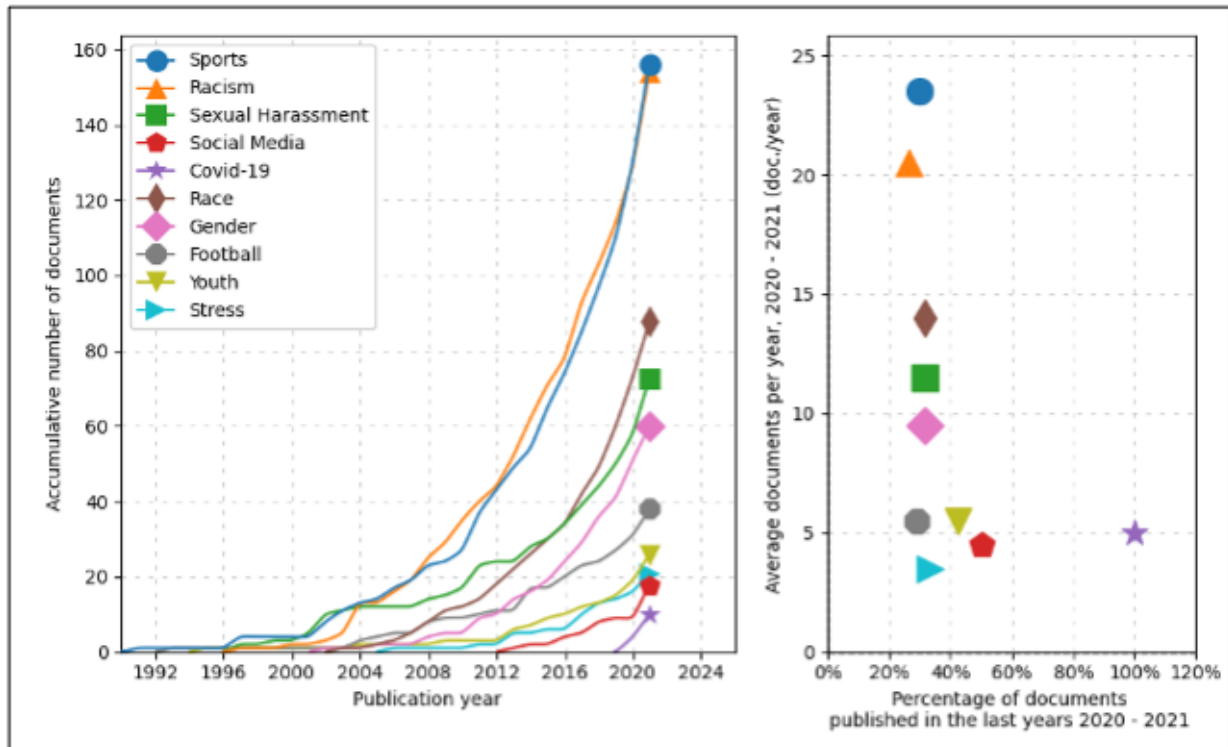
The frequency with which keywords appear in VOSviewer is proportional to the size of the node (see Figure 5). Lines represent relationships between keywords. The strength of the nexus link depends on the thickness of the line, which indicates the degree of co-occurrence. Figure 5 illustrates the author's keyword in an overlay diagram, highlighting its link to other keywords through the use of color,



**Figure 4.** Top institution



**Figure 5.** Overlay visualisation of the co-occurrence of authors' keywords



**Figure 6.** Trending topic author keyword

node size, text size, and connecting line thickness. Based on co-occurrence with the author's keyword analysis unit, the criteria used are the number of keywords that appear at least 15 times. From 3, 883 keywords, 42 meet the threshold.

The VOSviewer results allow us to conclude that the most used keyword in 2015 and 2016 was "racism" with 163 occurrences and 169 total link strength. Then next are "sexual harassment" (59, 68), "football" (41, 57), "ethnicity" (22, 38), "sexual abuse" (23, 32), "identity" (24, 31), "masculinity" (24, 31), "children" (27, 35). The most recent keywords starting after 2019 are "mental health" with 40 occurrences and 43 total link strength. Other keywords are "social media" (21, 33), depression (19, 26), and "abuse" (15, 22).

ScientoPy can identify trending topics by examining the top author keywords with the highest AGR (as described in the "Topic growth indicators" section). Figure 6 illustrates the evolutionary plot of the most popular trending topics in the field of harassment and bullying in sports. This evolution plot plots the cumulative number of documents (on a logarithmic scale) versus the year of publication on the left hand side. Thus, the first row on the X-axis represents the year the topic research was started, and the last line on the Y-axis represents the total number of documents published for each topic. The Y-axis on the right represents the AGR of each topic for the period 2020–2021, and the X-axis represents the PDLY. We can use this graph to determine which topics have higher AGR and higher PDLY. As a result, the trending topic with the largest absolute growth

is "sports", while the trending topic with the largest relative growth is "covid-19".

The author's keyword "sports" has become the most used keyword in the last two years. With a total of 157 documents, AGR (07.00), ADY (23.05), PDLY (29.09), and H-index 26, the keyword "sports" became the keyword with the largest absolute growth, while "covid-19" became the keyword with the highest growth. largest relative (100.00), and the H-index (4). Other keywords in positions three, four, and five respectively have AGR, ADY, PDLY, and H-index values of "Racism" (155, 07.05, 20.05, 26.05, 23), "Race" (88, 02.00, 14.00, 31.08, 19), and "Sexual Harassment" (73, 04.05, 11.05, 31.05, 21).

## Discussion

Negative interpersonal interactions among athletes, expressed as bullying and harassment, were singled out as an important social issue along with other important issues such as athlete trauma, doping use, hopelessness, and deception [5, 38]. Despite the attitude of the public and sports professionals that bullying in sports should be prohibited [39], over the past ten years, scholars from many countries have examined this sporting phenomenon increasingly studied and analyzed [39, 40, 41, 42, 43, 44, 45]. However, evaluating this phenomenon and comparing the obtained data with other data presents many difficulties. Rejecting the cultural context of a particular nation is usually the result of a lack of adequate and reliable measurement techniques [3].

Based on an examination of the research area, the findings reveal that harassment and bullying in sports is dynamic and involves many other disciplines, both in the context of sports science and in other fields. Psychology, sociology, culture, gender, ethnicity, are starting points for a better understanding of harassment and bullying in sports. This information can make it easier to understand trends in harassment and bullying research publications in sports. The evidence can be used by researchers to select the best academic publishing portal for their reference. These statistics can be used by practitioners to assess previous research conducted by other researchers.

The three most well-known authors on the field of harassment and bullying in sports are Hylton, K. (14 documents), Fasting, K. (12 documents), and Puhl, R.M. (12 documents). The ability to appreciate the works of such published authors helps future readers and researchers. The fact that key authors are listed in the research spreads the word about their work and increases their credibility. In addition, future readers and researchers will be able to identify well-known authors who have written about harassment and bullying in sports, with whom they are most likely to work together in the future.

The most frequently used keywords were, explicitly, "sports" (181 occurrences), "racism" (163 occurrences), "bullying" (122 occurrences), "adolescents" (134 occurrences), and "physical activity" (121 occurrences), allowing future readers and researchers to decide which one to use when analyzing documents. A further interesting finding of this study is that, as shown in Figure 6, "covid-19" is the 10th topic on the list, which has the highest PDLY (100%). "Social Media" is the 9th topic on the list, which has a PDLY of 50%. However, in the context of studies of harassment and bullying in sports, "youth" and "race" have PDLY (42.03% and 31.08%). Sports organizations in Canada do not differentiate between children, youth and adults when it comes to harassment policies. However, the treatment of children and youth in sports was the driving force behind the policy, and since then, the most significant and publicized incidents of abuse have almost always involved children and adolescents as victims [46]. Several studies have looked at variables that might reduce the relationship between bullying and racial and ethnic background, despite academic suggestions that the likelihood of being bullied in school is grouped by race and ethnicity [47].

The list of institutions in Figure 6 provides valuable information on research into harassment and bullying in sports by academics and professionals from various organizations. Understanding research professionals is the cornerstone of research on harassment and bullying in sports. The University of Toronto, Canada, has 22 publications, AGR (00.05), ADY (03.05), PDLY (31.08), and H-index (11) being the

most active educational institutions or institutions in publishing papers related to harassment and bullying in sports. One of the efforts that have been made to fight harassment and bullying in sport is the 2007 IOC Consensus Statement on Sexual Harassment and Abuse in Sport, which is expanded in this Consensus Statement, which also provides more evidence about forms of psychological, physical, and neglectful harassment and abuse [4].

Given the discussions contained in this study, researchers on harassment and bullying in sports were most interested in "sports", "racism", "bullying", "adolescents", and "physical activity". In addition, more and more research on harassment and bullying in sports is focusing on "sports", "racism", "sexual harassment", and "gender." This valuable information provides future readers and researchers with the publication trends of harassment and bullying in sports. This suggests that a scientometric review allows discussion of critical aspects of previous research by leveraging the understanding of previous scholars to advance intellectually.

## Conclusions

The main purpose of this scientometric review is to examine the global evolution of research into harassment and bullying in sports. Recent queries were examined in the Scopus and WoS databases using search strings ("sport\*" OR "competitive game" OR "physical activity" OR "pastime" AND "bully\*" OR "ethnic bullying" OR "racist\*" OR "pester\*" OR "annoyance" OR "nuisance" OR "persecut\*" OR "bedevilment"). This database search yielded 2, 698 papers. After data reconciliation, this study examined 1, 883 unique entries from both databases, with 1, 297 unique articles from WoS and 586 unique articles from Scopus.

This study has demonstrated the remarkable growth trajectory of harassment and bullying research in sports since 2015. Research on harassment and bullying in sports is gaining traction due to the involvement of academics and practitioners, which requires a lot of scrutiny in this area. Harassment and bullying in sports is an inseparable part of the lives of many people, so efforts are needed to deal with and minimize the occurrence of these acts on a larger scale. Of course, this has an unfavorable impact psychologically, emotionally, and socially on athletes, coaches, and officials. indirectly by attracting and facilitating current and future researchers who want to learn more and be interested in the topic of harassment and bullying in sports.

The limitations of this study are mainly due to the search strings that have been implemented. If additional keywords are used, the discussion may be slightly different. However, this analysis is only a starting point that can be disseminated by more in-depth investigation, such as a scope review or

systematic literature review. These findings can develop a theoretical framework, map the current state of the field, and quickly identify gaps in scientific research. Furthermore, the findings of this study have been projected to stimulate the development of new ideas as a result of keyword analysis, enabling the more effective dissemination and communication of scientific work related to harassment and bullying research in sports and the

formation of new, more relevant concepts and ideas. This research is expected to be a stepping stone for future work in developing research on harassment and bullying in sports.

### Conflict of interest

The authors state that there is no conflict of interest

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## Special and preventive exercises for hamstring muscles in the training process of experienced football players

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Authors' Contribution: A – Study design; B – Data collection; C – Statistic analysis; D – Manuscript preparation; E – Funds collection

### Abstract

**Background and Study Aim** In-depth analysis of electrical activity of certain muscles in athletes contributes to improvement in the technique of physical actions. Hamstring muscles are an important factor for making physical actions by experienced football players. The purpose of the study consisted in substantiation for factors of optimization of physical capacity to work in experienced football players.

**Material and Methods** The study involved 20 experienced football players (n=20, aged 18-33, the period of going in for football  $\geq 10$  years). We used equipment of M-TEST computer electromyography device manufactured by research and development enterprise DX-Systems (Kharkiv, Ukraine). The maximum bioelectrical activity (MBA) of *m. biceps femoris*, *m. semitendinosus* and *m. semimembranosus*, which are hamstring muscles (HM), depending upon the angle of applied effort. The study was conducted with positions of the lower leg at angles of 180°, 165°, 145° and 125°. We used two-way analysis of variance and regression analysis. The fact that the distribution was normal was checked by Shapiro-Wilk W test.

**Results** Conditions for manifestation of the maximally effective realization of contractile abilities of HM were determined. Positions of the body and lower extremities for the largest overlaying of myofilaments in sarcomeres of HM were determined. Conditions of using external movement-disorganizing influence for HM were revealed. Models for special activity of experienced football players were systematized.

**Conclusions** HM will manifest their MBA in case of the coaxial position of the trunk and lower extremities. The angle of the lower leg position, equal to 180°, is the optimum one for the maximum overlaying of sarcomeres in the above muscles. Exercises with a component, which destabilizes the body position, are the most effective ones for realizing contractile abilities of HM.

**Keywords:** electromyography, hamstring muscles, special exercises, preventive exercises, football.

### Introduction

The dynamics of team sports involve contraction of most muscles in the locomotor apparatus [1, 2].

These conditions necessitate development of effective preventive methods of training with integrated optimization of all its components [3, 4, 5]. One of these components is based on a thorough analysis of the essence of contractile abilities of the muscle with respect to the angle of applied effort [3]. Therefore, it is necessary to investigate diarticular hamstring muscles (HM) that flex the knee, extend the thigh and regulate the athlete's body movement forwards.

In jumps, preservation of the body position during a contact with an opponent or performance of technical element the high-priority task consists in maintaining the vertical body position [6, 7, 8]. The above elements mostly engage muscles of the

back and hamstring ones, which create powerful extending pulls [3, 7, 9].

The contractile ability of HM is interrelated with a change in the position of adjacent joints [6]. Hence the question arises concerning their relationship with location of the lower extremity segments and trunk. It is necessary to study the ability to maintain an intended body position (posture) in the structure of performance of a certain technical element in optimum conditions for manifestation of force [10]. Maintenance of the constant posture is only an individual case of positional activity of muscles [10, 11]. Usually, in the process of specific activity of football players there is a change of their postures, transition from movement to some or another posture, each time engaging HM [12, 13]. Each such case places its demands on the initial position, conditions of a technical element [14]. It precedes the moment of posture fixation, maintenance (restoration) of the body balance [3, 15].

In team sports, a single technical element

can be regarded as a complete movement [16]. A systemic structural analysis makes it possible to isolate parts of a technique, its elements in time, which are called phases [1, 4]. The preparatory, basic (working) and final phases are separated with a proper redistribution of the emphasis of physical effect on a certain muscular area. The basic phase is aimed at solution of the movement task of the given technique [13, 14, 16]. During its final phase the football player tries to take up a stable initial position of balance. The latter is provided by isotonic muscular contraction required for further actions [3, 17, 18].

At present, detection of the position of the above segments becomes the element, which requires a thorough study. Gordon et al., Zatsiorsky and Verkhoshansky examined the relationship between the force and the muscle length. They noticed that it was the maximum one with a certain average length [10, 11, 19]. They simultaneously registered the sarcomere length, force of pull and overlaying of actin-myosin filaments. The largest overlaying of the above areas was accompanied by the maximum manifestation of force. A certain average length, with which contractile components of the muscle can manifest their maximum effort, is called the “length of rest” [10, 11].

It becomes an urgent problem in the professional sport to conduct studies for revealing localization of an effort on a certain muscle area or for generalized action on their group. Dependence upon the initial position (the initial angle and lever) of a movable segment is a significant component [3, 10]. As far as further researches are concerned, it becomes necessary to choose a set of special exercises for practical realization of results of this study and coordinate with the general structure for training qualified football players as special and preventive means [3, 13]. The above conditions for using special exercises will be essential in the structure of optimization of the level of technical fitness too.

The aim of study. Scientific-methodological substantiation of force factors for optimization of physical capacity to work in experienced football players by data of interference electromyography (IEMG) of HM. Development of sets of exercises, regulation of conditions for their use.

## Materials and methods

### *Participants*

The study involved 20 experienced football players (n=20, aged 18-33, the period of going in for football > 10 years). We received informed consent for participation in the experiment.

### *Research Design.*

The study was aimed at detection of the optimum angle in the position of the lower leg for manifestation of MBA of HM in the exercise “knee flexion in

prone position”. Interference electromyography was used. The study was performed with help of an M-TEST computer electromyography device manufactured by research and development enterprise DX-Systems (Kharkiv, Ukraine) and intended for registration and analysis of electromyograms (EMG). Ag/AgCL Skintact Easitab RT34 electrodes, which have an adhesive base, were used.

Immediately before making our examination we conducted warming up on an ellipsoid stair stepper. It lasted 10 minutes with a gradual increase of loading from 30 to 120 W at a rate of 80 steps per minute. Then there was a rest for 5 minutes with doing exercises for development of flexibility.

We used electrodes with an arbitrary interelectrode distance. The fastening of the active electrode was provided in the muscle innervation area (over the belly of muscle), in the projection of the movement area. The reference electrode was in the proximal area of the tendon part.

The ground electrode was placed in the lower third part of the opposite lower leg and connected to the proper terminal on the electrode panel of the electromyograph.

The advance speed of the “chart” was 200 mm·s<sup>-1</sup>. Amplification (displayed amplitude) of the signal was 5 mV·cm<sup>-1</sup> with the current value of deviation rate equal to 40 ms·cm<sup>-1</sup>. The current value of an increase of deviations was equal to 0.9 mV·cm<sup>-1</sup>.

The angle in the position of a movable segment was determined on the basis of its previous measuring on a mechanical training machine and with help of photogoniometry.

In the process of our study we processed electromyograms during 5-second manifestation of the maximum effort followed by a rest for 1-1.5 minutes.

The task was performed with an ability to regulate the angle and the lever of counteraction (by changing the angle of knee flexion) alternately with the right and left legs. It was envisaged to perform the exercise with the position of the extended foot, the toe being in the plane parallel to the sagittal one. The study used angles of 180°, 165°, 145° and 125° (Fig. 1).

The initial position was regulated by design features of the training machine (thigh position at its flexion angle equal to 35°).

The coaxial location of the pelvic girdle segments and trunk with the vertical body position is caused by the content of a special component [3]. This condition can be modelled on the basis of special exercises. Two following blocks are envisaged.

Block 1: *the horizontal body position*. Its basic elements include rear lying, rear lying with forearm support and legs resting on an unstable structure (Fig. 2a). The element of swinging with the other extremity is regarded as an additional component,

which disorganizes maintenance of the position. In these positions the basic element of physical effect consists in counteraction of the muscles, which keep the horizontal position of the body [14].

Block 2: *the vertical body position* with performance of a certain technical element in conditions of an external counteraction. It is mostly observed during frontal movement in the sagittal plane, performance of a swinging element or a counteraction from behind. *Standing on an unstable*

*structure* (Fig. 2b) and *with an external counteraction* (Fig. 3a,b) (a rubber rope) provide for a generalized destabilizing effect on the support extremity.

The conditions for use of exercises standing on a hemisphere, in conditions of studied IEMG data on the basis of a set of exercises, developed by us, are as follows (Fig. 2b, Table 1).

*Statistical analysis*

Descriptive statistics, testing of the hypothesis



a)



b)

**Figure 1.** Positions of the thigh at an angle of 35° and of the lower leg at an angle of 180° (a) and 145° (b).



a)



b)

**Figure 2.** Fragments of a training session with special and preventive exercises for hamstring muscles by IEMG data (on a hemisphere).



a)



b)

**Figure 3.** Fragments of a training session with special and preventive exercises for hamstring muscles by IEMG data (with an external counteraction).

**Table 1.** Special and preventive exercises in the position “standing on a hemisphere”.

No.	Content	Duration	Rest	Organizational-methodological recommendations
1.	A jump onto a hemisphere on the left leg; return of a ball by air with the middle part of the bridge of the foot.	30''	1'	Alternate performance of the exercise with the right and left leg. Before the jump onto the hemisphere 2-3 quick steps in place are made. Landing onto the hemisphere necessitates flexion of the support leg towards the force of gravity with subsequent extension during performance of the technique. The foot of the flexed support leg is located on the surface of the training machine in its upper marginal area. Performance of the technique is followed with movement backwards at a slack pace.
1.1.	A jump onto a hemisphere on the right leg; return of a ball by air with the middle part of the bridge of the foot.	30''		
2.	A lateral jump onto a hemisphere on the left leg; return of a ball by air with the middle part of the bridge of the foot.	30''	1'	Alternate performance of the exercise with the right and left leg. Before the jump onto the hemisphere 2-3 quick steps in place are made. Landing onto the hemisphere necessitates flexion of the support leg towards the force of gravity with subsequent extension during performance of the technique. The foot of the flexed support leg is located on the surface of the training machine in its upper marginal area. Performance of the technique is followed with movement sideways at a slack pace.
2.1.	A lateral jump onto a hemisphere on the right leg; return of a ball by air with the middle part of the bridge of the foot.	30''		
3.	A jump onto a hemisphere on the left leg; return of a ball by air with the inner side of the right foot.	30''	1'	Alternate performance of the exercise with the right and left leg. Before the jump onto the hemisphere 2-3 quick steps in place are made. Landing onto the hemisphere necessitates flexion of the support leg towards the force of gravity with subsequent extension during performance of the technique. The foot of the flexed support leg is located on the surface of the training machine in its upper marginal area. Performance of the technique is followed with movement backwards at a slack pace.
3.1.	A jump onto a hemisphere on the right leg; return of a ball by air with the inner side of the left foot.	30''		
4.	A lateral jump onto a hemisphere on the left leg; return of a ball by air with the inner side of the right foot.	30''	1'	Alternate performance of the exercise with the right and left leg. Before the jump onto the hemisphere 2-3 quick steps in place are made. Landing onto the hemisphere necessitates flexion of the support leg towards the force of gravity with subsequent extension during performance of the technique. The foot of the flexed support leg is located on the surface of the training machine in its upper marginal area. Performance of the technique is followed with movement sideways at a slack pace.
4.1.	A lateral jump onto a hemisphere on the right leg; return of a ball by air with the inner side of the left foot.	30''		
5.	A jump onto a hemisphere on the left leg; return of a ball by air with the right thigh.	30''	1'	Alternate performance of the exercise with the right and left leg. Before the jump onto the hemisphere 2-3 quick steps in place are made. Landing onto the hemisphere necessitates flexion of the support leg towards the force of gravity with subsequent extension during performance of the technique. The foot of the flexed support leg is located on the surface of the training machine in its upper marginal area. Performance of the technique is followed with movement backwards at a slack pace.
5.1.	A jump onto a hemisphere on the right leg; return of a ball by air with the left thigh.	30''		
6.	A jump onto a hemisphere on the left leg; return of a ball by air with the right thigh.	30''	1'	Alternate performance of the exercise with the right and left leg. Before the jump onto the hemisphere 2-3 quick steps in place are made. Landing onto the hemisphere necessitates flexion of the support leg towards the force of gravity with subsequent extension during performance of the technique. The foot of the flexed support leg is located on the surface of the training machine in its upper marginal area. Performance of the technique is followed with movement sideways at a slack pace.
6.1.	A jump onto a hemisphere on the right leg; return of a ball by air with the left thigh.	30''		

about the kind of distribution, two-way analysis of variance and regression analysis aimed at finding of the optimum position for the extremities were used. The fact that the distribution was normal was checked by Shapiro-Wilk W test. This criterion is realized in some software programs, namely OriginPro, which was used at this stage of our study.

**Results**

Our analysis of IEMG of HM revealed a dependence of manifestations of muscle contraction upon the relationship between the hip and knee joints. When the angle of thigh flexion was 35°, the angle of MBA manifestation in HM was 145° (Fig. 2b). After a change in the angle of the thigh position by 35° the lower leg position also changed by 35 degrees for manifesting MBA. When the trunk and thigh were in the same plane, manifestation of MBA was with the lower leg angle of 180° .

In the exercise “knee flexion in prone position”

we observed uniform distribution of bioelectrical activity on HM (Fig. 4).

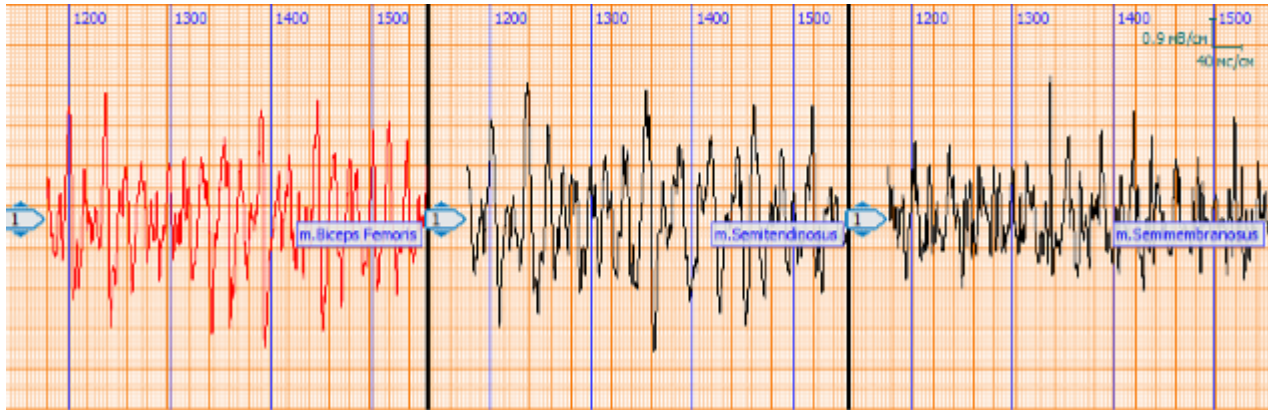
A visually asymmetrical change in the amplitude of curves can be observed, when a flexed knee rotates outwardly or inwardly.

In compliance with the conclusion of two-way dispersion analysis we constructed a polynomial regression model of the third order. A smaller polynomial order produced a significant scatter of theoretical and experimental data (Fig. 5).

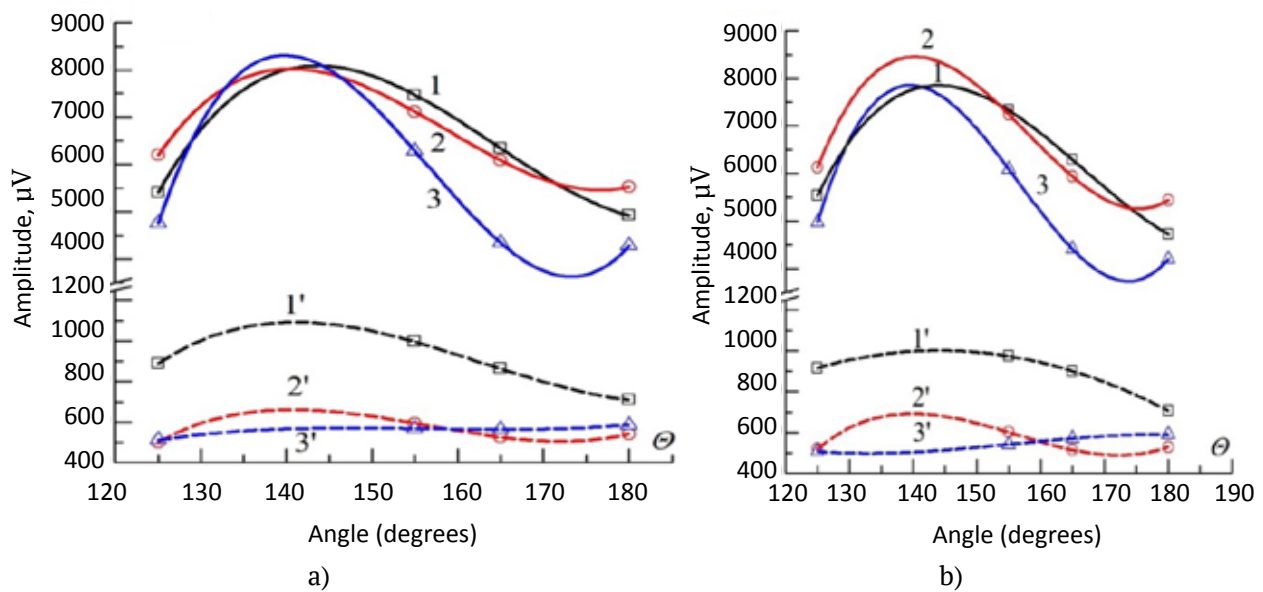
The regression equations gave us the optimum angles, which corresponded to the maximum values of the studied parameters.

The positions, studied by us, are those of the largest overlaying of actin-myosin filaments in a sarcomere with MBA. We assume that it is these positions that are positions of the “length of rest” for HM [10, 11].

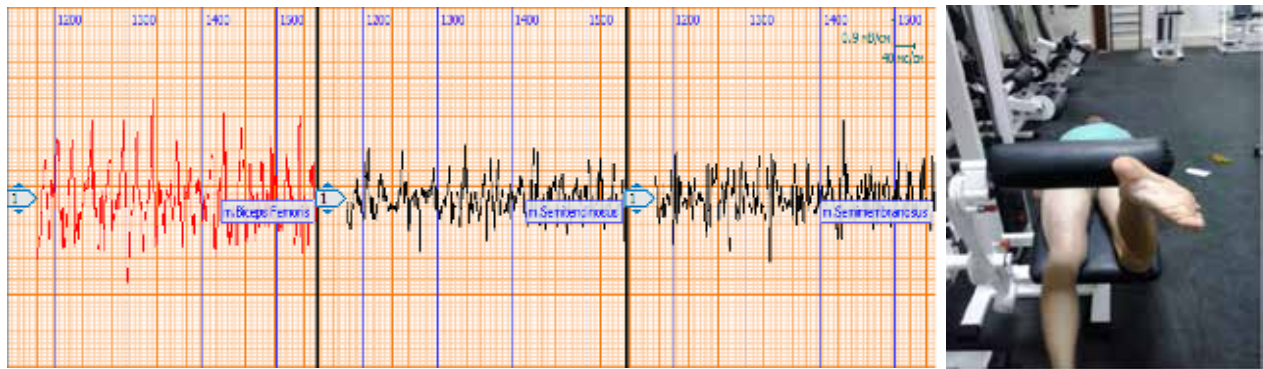
We also determined redistribution of bioelectrical activity of HM in outward or inward



**Figure 4.** Fragment (IEMG) at knee flexion angle of 145°



**Figure 5.** Regression dependence with experimental points of the maximum (continuous lines) and mean (dashed lines) amplitude of myograms for the right (a) and left extremity (b): 1, 1' – m. biceps femoris; 2, 2' – m. semitendinosus; 3, 3' – m. Semimebranosus; vertical axis X (µV), horizontal axis Y (angle) [15]



**Figure 6.** IEMG fragment at the flexion angle of  $125^\circ$  with external rotation of lower leg.

rotation of the knee. Supination increased contractile manifestations of *m. biceps femoris* with their similar decrease in *m. semitendinosus* and *m. semimebranosus* (Fig. 6). Pronation increased contractile manifestations of *m. semitendinosus* and *m. semimebranosus* with their similar decrease in *m. biceps femoris*.

### Discussion

Performance of all specific movements is in direct relationship with spatial transfer of extremity segments. A well-defined biomechanical structure is envisaged in the organization of contraction of some or another muscle [8, 9, 20, 21, 22]. All specific movements, whose structure includes flexion-extension of segments of the lower extremities, provide for movement in the sagittal plane, abduction-adduction in the frontal plane or other ones parallel to them [3]. It is possible to isolate several basic movements used by football players during their training and competitive processes [3, 14, 17]. These movements are as follows: *knee flexion* (it engages HM and lower leg muscles during a frontal body movement in the sagittal plane), *thigh extension* (with a straight leg) as a basic element during a frontal movement, etc. [3]. We would like to note the preventive content of the set of exercises, suggested by us. Its structure provides position for the maximum realization of contractile abilities by the muscles in conditions, which resemble competitive activity. The use of unstable structures as an additional factor, which disorganizes the basic movement, will involve into contraction several areas of muscles [3, 8]. These are both basic muscles, which make counteraction, and small ones, which are responsible for “fine” regulation of the basic movement. Harmonious development of all muscle areas, engaged into a specific movement act contains more than only a preventive component [15]. Optimization of technical skills of qualified football players is a significant factor [1, 23, 24, 25].

Performance of technical elements such as a pass, a kick of a ball, a transfer with a sudden change of direction, etc., satisfies the limits determined by us. In case of our study the priority consisted in

the choice of exercises, where HM could manifest their “positional activity” [11]. This fact confirms Zatsiorsky’s theory about a change of strength abilities of the muscle in retraction and maximum extension of the motor area [11] with a complex combination in exercises with engagement of “deep layer” muscles, which will have preventive content [26].

These exercises are in the same plane of regulation and serve as a contextual continuation of FIFA Medical Assessment and Research Centre (F-MARC) “FIFA 11+” sets of exercises “Strength, coordination, balance” [27]. They were updated by us and today their structure unites several blocks of exercises with an asymmetric direction in different planes. The presence of an additional destabilizing component (a hemisphere, an unstable platform, etc.) is an important component. We suggest using the above sets of exercises during the basic period of training, general preparatory and special preparatory stages of the preparatory period and in the structure of the competitive period as an element of the preparatory part of training.

We would like to emphasize existence of direct relations between competitive activity components and dynamics of movement of lower extremity segments during use of special and preventive exercises [3]. The higher is the level of development of physical qualities, the more abilities for perfect mastering of the technique and its realization exist. The higher is the technique, the better physical and other qualities are realized [8, 9, 28, 29]. Our above revealed positions and movements of kinematic links correspond to the structure of competitive activity of professional football players and everyday human activity.

The movement of a kinematic link in the exercise “knee flexion in prone position” for HM was not systematized before from the position of contractile ability. Only muscle function with respect to the direction of movement was examined [3]. The scientific-methodological component of the aspect of load redistribution on the area, which contracts, was optimized.

Kendall et al. [6] examine the exercise for HM,

studied by us, from the position of a diagnostic attempt, where the foot is in the plane parallel to the sagittal one.

The redistribution of bioelectrical activity of HM depending upon rotation of the lower leg, which we revealed, will optimize components for carrying out muscular-fascial testing. This will also make it possible to qualitatively regulate conditions of a local physical effect on the area of contraction in functional imbalance [30, 31].

## Conclusions

The research results show the necessity of the following:

- to use the revealed positions for manifestation of MBA of HM in the training process of experienced football players;
- to aim for symmetrical relationships of adjacent angles “thigh-trunk” and “lower leg-thigh” in special exercises with standing;
- to maintain the coaxial position of the lower

extremities and trunk in special exercises “rear lying”;

- to regulate load redistribution on HM with the inward or outward rotation of the knee;
- to use redistribution of contractile abilities of HM depending upon rotation of the knee in the block of muscular-fascial testing.

Prospects of further studies consist in conducting force-measuring studies in proper positions.

Redistribution of the contractile influence on HM depending upon rotation of the knee necessitates further studies.

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## Conflict of interests

The authors report about absence of any conflict of interests.

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