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Research article

THE IMPACT OF LIMITED MOVEMENT DURING THE COVID-19 PANDEMIC ON THE LEVEL OF PHYSICAL ACTIVITY AND MORPHOLOGICAL CHARACTERISTICS

UDC 796.012:616-036.21

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Abstract. *The aim of the study was to determine the impact of two months of relative motor inactivity caused by restriction of movement during the period of the Covid-19 pandemic on changes in the level of physical activity and morphological characteristics of the respondents. The study was conducted on a sample of 48 female students aged 20±0.6 years. Data for the selected variables for assessing the level of physical activities and morphological characteristics were collected with standardized instruments at two time points. A comparative analysis of the average values for assessing the level of physical activity reveals a significant negative impact of eight weeks of relative motor inactivity. The energy expenditure in all three types of physical activities (light, moderate and vigorous), and consequently the total expenditure, expressed in the Metabolic Equivalent Task, significantly decreased during the period of inactivity. Statistically significant differences were found only for hard work and total work during the week ($p < 0.001$), while there were no significant differences in light and moderate physical activities. The analysis of average values for the assessment of selected morphological variables proved that the period of inactivity caused the deterioration of morphological characteristics. Statistically significant negative changes occurred in all five monitored body dimensions of the respondents. During the experimental treatment of inactivity (ETI), body mass, the Body Mass Index, body fat percentage and waist size increased significantly ($p < 0.001$). At the same time, the lean component decreased significantly ($p = 0.007$).*

Key words: *Lockdown, Relative Motor Inactivity, Energy Expenditure, Body Status*

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INTRODUCTION

Physical activity (PA) is defined in theory as any movement derived from skeletal muscle activation that requires energy expenditure and complex behavior including sports and other physical activities (Plasqui & Westerterp, 2007), but at the same time also defined as the promotion of positive childhood behavior that can lay the foundation for overall health (U.S. Department of Health and Human Services, 2010).

A number of studies dealt with the engagement of students in sports and recreational activities in order to determine the amount and structure of their movement during the average week. In most of these studies, the International Physical Activities Questionnaire (IPAQ) was used as an instrument to collect data. Almost all studies (De Vahl et al., 2005; Romanov et al., 2014; Sullum et al., 2010; WHO, 2018b) reported very low levels of PA for students. This data is associated with poor fitness and majority of respondents stated that exercise presents a great effort for them (Pantelić et al., 2010).

In recent years, there has been growing interest in the physical activity and nutrition of children and youth (including students), as evidenced by numerous studies (Lopez-Sanchez et al., 2020; Basterfield et al., 2011; Boreham & Riddoch, 2001; Janssen & LeBlanc, 2010; Pate et al., 2002; Suder & Chrzanowska, 2015; Tolfrey et al., 2000; Trost et al., 2001). These studies looked at the problem of PA and health, proved that low levels of physical activity greatly affected the increased risk of obesity and decreased physical ability. Obesity can be classified using a number of methods, each of which has its pros and cons (Norgan, 2007; Wilson et al., 2019). The Body Mass Index (BMI) is correlated with the PA and student sedentary behavior. Higher BMI is associated with higher levels of sedentarity and lower levels of PA (Cooper et al., 2015; Jago et al., 2020; Schwarzfischer et al., 2019).

The World Health Organization (WHO) on 11 March 2020 declared a pandemic caused by the SARS-CoV-2 virus. In order to protect the population from infection in the Republic of Serbia, on 15 March 2020 a state of emergency was declared. A key safety, health measure, the “lockdown" limited the free movement of people, which had an impact on the regular physical activities of students. Studies have shown that, in different countries, student PA levels (walking, moderate, high, and total PA) were reduced during the Covid-19 pandemic (Lopez-Valenciano et al., 2021; Barkley et al., 2020).

The aim of the study was to determine the impact of two months of relative motor inactivity caused by restriction of movement during the Covid-19 pandemic and their impact on changes in the PA level and morphological characteristics of the respondents.

METHODS

Study Design

An experimental longitudinal study with non-probabilistic appropriate sampling, which would monitor changes in the physical characteristics and levels of physical activity of young women, under the influence of aerobic exercise, was supposed to start in early March 2020. However, due to the introduction of a state of emergency that lasted almost two months (until 6 May, 2020) schools and colleges were closed. As the sample of this study consists of female students, the implementation of the experiment was stopped due to lockdown. Initial measurements were already carried out, which resulted in using collected data to analyze changes in the PA level and physical characteristics of the same respondents, which occurred during the two-month limited movement. Therefore, instead of the originally planned application of the experimental exercise factor, the forced experimental inactivity factor was applied due to the Covid-19 pandemic.

The research draft was re-created as a field experiment that monitored the impact of physical inactivity on the subjective assessment of the PA level and changes in morphological characteristics during the period of lockdown.

During the process of collecting empirical data, the self-assessment of the PA level, the IPAQ questionnaire was distributed to the respondents at the beginning and end of the state of emergency. At the same two time points, variables for assessing morphological characteristics were measured (body mass, BMI, percentage of fat, lean body mass and waist size). All data were collected using standardized instruments whose metric characteristics were checked in previous studies.

Sample

The study was carried out as an experimental study with a suitable sample formed by the voluntary participation of female students of the Academy of Applied Studies Belgrade, in Belgrade. The study was conducted on a sample of 48 female students, moderately physically active, aged 20 years (±6 months). Moderate physical activity as the dominant kind was used for the homogenization of the sample, because there were no students belonging to the category of highly active, and students whose energy expenditure was less than 600 MET-minutes/week (Metabolic Equivalent Task - MET) were not expected to quickly change their attitudes in relation to the PA and exercise.

Before the start of the experiment, the purpose of the study was explained to the respondents along with the measurement protocols. Each of them gave their written consent to participate in the research. All procedures were carried out in accordance with the provisions of the Helsinki Declaration on work with people (WMA, 2013).

Variables and instruments

Each respondents was registered with the following four variables for assessing their PA level: light (low intensity PA), moderate (moderate intensity PA), vigorous (vigorous intensity PA) and total work (sum of light, moderate, and vigorous). The energy expenditure in all four forms of physical activity (light, moderate, vigorous and total work) is expressed in MET.

To assess the PA level on a weekly basis, a standardized IPAQ questionnaire was used, distributed to the respondents at the beginning of the experiment and after eight weeks. This study used a shorter version of the questionnaire published on the website of the Association for Sports and Sports Medicine (USMS, 2020).

The IPAQ has good metric characteristics confirmed in several studies (Craig et al., 2003; Hallal & Victoria, 2004; Hagströmer et al., 2006). It is the world's most widely used physical activity questionnaire (Van Poppel et al., 2010). The IPAQ measures the frequency, duration and intensity of physical activity in four areas of life: (1) work, (2) travel, (3) housework, and (4) free time. The results are expressed in MET, where one MET is equivalent to metabolic consumption at rest. According to international standards (Ainsworth et al., 2011; IPAQ group, 2005) PA can be broken down into three categories: (1) low PA (less than 600 MET per week), (2) moderate PA (from 600 to 3.000 MET total or 480 MET heavy PA) and (3) high (more than 3.000 MET in total or 1.500 MET heavy

PA). For the calculation of the PA index, IPAQ guidelines were used (Ainsworth et al., 2011) according to which the heavy PA is worth 8 MET, moderate PA 4 MET, light about 3 MET. Moderate walking (a walk) for example corresponds to a value of 3.3 MET.

Each respondent had assigned values for the following five variables for the evaluation of morphological properties, in the beginning (the initial measurement) and after the lockdown (the final measurement): body mass, BMI, the percentage of fat in the body composition, the lean body mass of the body and waist size.

To measure body mass (BM), percentage of body fat, and lean body mass (LBM) bioelectric impedance was used and the electronic portable scale "Tanita" (model BC-543). BMI was calculated as the ratio of body mass and square of body height, i.e. BMI = kg/m^2 (Blackburn & Jacobs, 2014; Keys et al., 1972). Waist size (WS) was recorded to evaluate abdominal fat mass. It was measured with a flexible strip with a measurement accuracy of 0.1 cm at the level of the middle distance of the lowest point on the rib arch and the highest point on the iliac crest of the pelvic bone. In addition to the variables that are monitored, body height was measured using a telescopic instrument (model SECA 220). Data were expressed in centimeters with an accuracy of 0.1 cm. This measurements were taken only once and were only used to calculate the BMI.

Statistical analysis

For each variable, at both time points of the experiment, the arithmetic mean (Mean) and standard deviation (SD) were calculated. The significance of the differences between the average values of the PA level before and during the limited activities and the average values of the variables for the assessment of morphological characteristics before and during the limited activities was checked by the T-test for dependent samples (Paired Samples Test). For the data related to the level of nutrition, which were assessed using BMI, a frequency distribution was made that enabled contingency analysis, i.e. the application of the Chi-Squared test. The SPSS 21.0 statistical program (IBM Corporation, USA) was used for the complete statistical analysis. All the conclusions were realized at the 0.05 level of significance ($p < 0.05$).

RESULTS

The comparative analysis of average values of PA levels before and after ETI (Table 1) revealed a significant negative impact of two months of inactivity. The energy expenditure, expressed in MET-s, in all three types of physical activities, for light (265.75 to 224.17), moderate (745.29 to 679.33), and vigorous (1067.09 to 788.17), and consequently on the total expenditure (2066.76 to 1712.50), decreased significantly during the period of limited movement. Statistically significant differences were found only for vigorous ($p < 0.001$) and total work ($p < 0.001$) during the week, while there were no significant differences for light ($p = 0.492$) and moderate ($p = 0.854$) PA. These data suggest that ETI did not have a proportional effect on changes in different PA levels, as the corresponding graph shows (Figure 1).

Table 1 The average PA values before and after the ETI

	Before ETI		After ETI		Paired Samples Test	
Work (MET)	Mean	SD	Mean	SD	t	p
Light	265.75	± 344.11	224.17	± 345.84	0.693	0.492
Moderate	745.29	± 470.11	679.33	± 441.00	0.854	0.397
Hard	1067.09	± 537.93	788.17	± 306.39	4.195	< 0.001
Total	2066.76	± 597.75	1712.50	± 637.83	4.204	< 0.001

Abbreviations: MET - metabolic equivalent task, ETI - experimental treatment of inactivity, SD - deviation from the mean value, t - T-test, p - significant

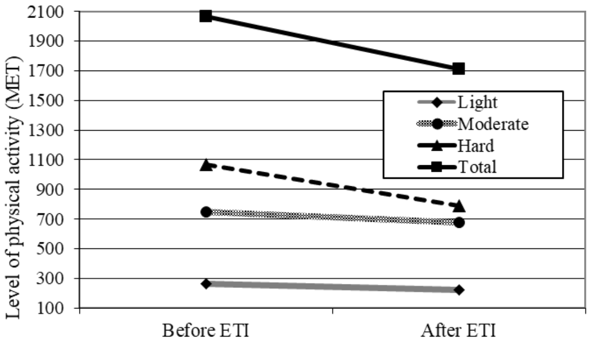

Fig. 1 Changes in the PA level before and after ETI

By comparing the average values of monitored body dimensions before and after ETI (Table 2), a significant negative impact of eight weeks of inactivity was observed. During ETI, the average values of the monitored variants increased significantly: BM (61.10 kg to 62.52 kg), BMI (21.71 kg/m^2 to 22.21 kg/m^2), body fat percentage (26.72% to 27.73%), and WS (77.92 cm to 79.25 cm), while LBM was reduced (42.47 kg to 42.13 kg). Inactivity had the greatest impact on BM ($p < 0.001$), BMI ($p < 0.001$), body fat ($p < 0.001$), and waist size ($p < 0.001$), but significance was not absent in the impact on LBM ($p = 0.007$), and as LBM was reduced, decreasing values were registered for the lean body component (Figure 2).

Table 2 The average values of variables for the assessment of morphological characteristics before and after ETI

	Before ETI		After ETI		Paired Samples Test	
Variable	Mean	SD	Mean	SD	t	p
BM (kg)	61.10	± 8.09	62.52	± 8.45	-6.713	< 0.001
BMI (kg/m^2)	21.71	± 2.56	22.21	± 2.65	-6.622	< 0.001
Body Fat (%)	26.72	± 5.56	27.73	± 5.29	-1.214	< 0.001
LBM (kg)	42.47	± 2.69	42.13	± 2.91	2.829	0.007
WS (cm)	77.92	± 6.58	79.25	± 7.01	-5.212	< 0.001

Abbreviations: BM - body mass; BMI - body mass index; LBM - lean body mass; WS - waist size; SD - deviation from the mean value; t - T-test; p - significant

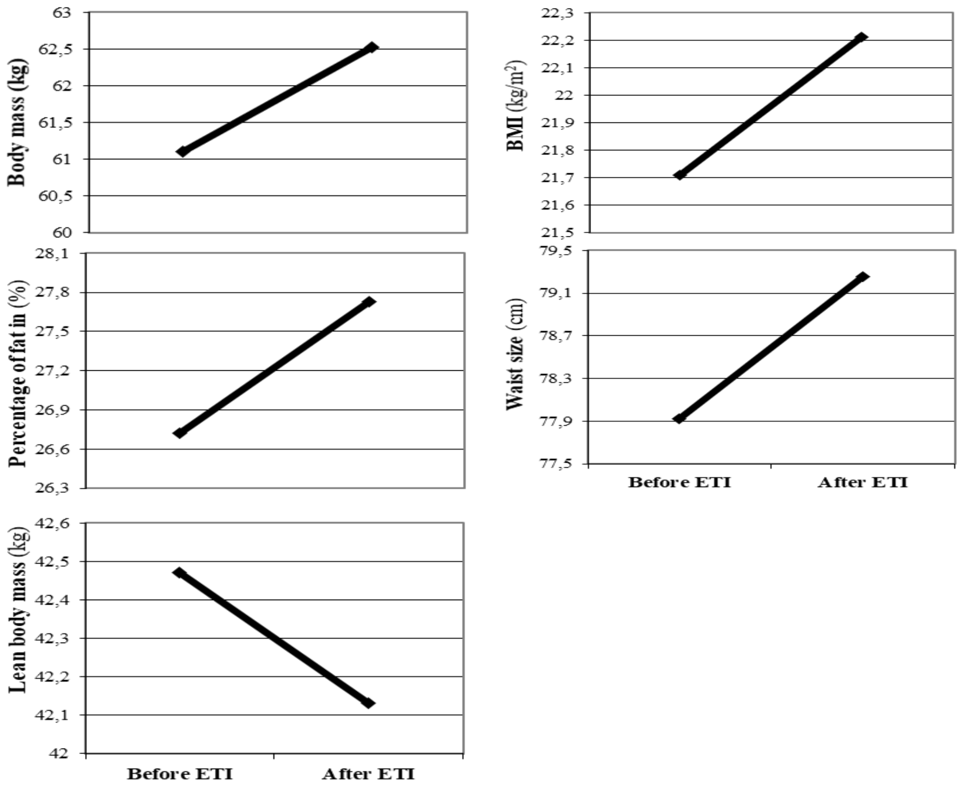

Fig. 2 The average values of variables for the assessment of morphological characteristics (body mass, BMI, body fat percentage, lean body mass and waist size) before and after ETI

Empirical frequencies (Table 3 and Figure 3) show that the sample is dominated by female students with normal body weight. Almost the same distribution of frequencies was obtained both before and after ETI (before ETI 81.3%; after ETI 87.4%). The only observed difference refers to the decrease in the number of underweighted respondents (before ETI 10.4%; after ETI 4.2%), who due to gained kilograms during inactivity, moved into the group of persons with normal body weight.

Table 3 Distribution of test subjects in relation to nutritional status before and after ETI

	Before ETI		After ETI	
Nutritional status	Number	Percentage	Number	Percentage
Underweight	5	10.4%	2	4.2%
Normal weight	39	81.3%	42	87.4%
Overweight	3	6.3%	3	6.3%
Obesity	1	2.1%	1	2.1%
Total	48	100%	48	100%

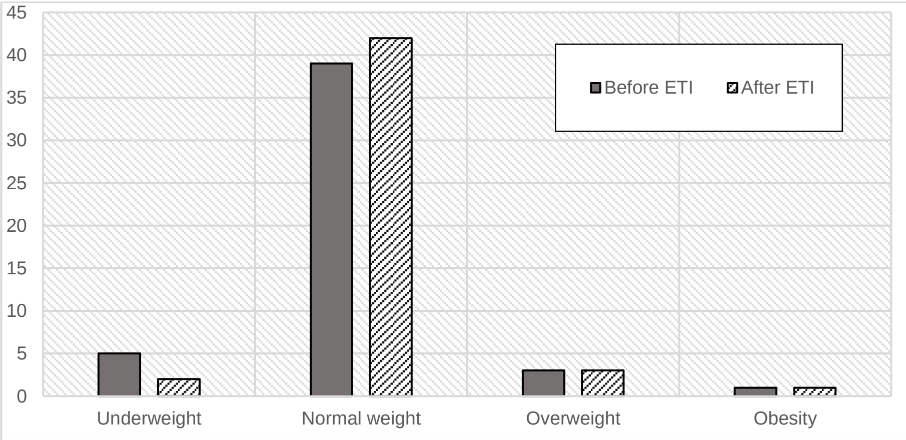

Fig. 3 Distribution of test respondents in relation to nutritional status before and after ETI

DISCUSSION

Based on the data collected with the IPAQ instrument, the level (extent and structure) of PA during one week before and during the last week of the limited movement was determined. The data are expressed in MET and represent an index of the energy consumption of the respondents, both total and separate consumption in individual PA of different intensity (light, moderate, and vigorous). The movement habits and morphological characteristics of the test respondents deviate from the average values that apply to the student population and were obtained in previous research. The respondents from the sample had a higher level of PA even before the ETI (the level of PA determined during the formation of the sample – before the start of the experiment, the respondents were categorized as persons with moderate PA) compared to the data obtained for the student population in previous research (De Vahl et al., 2005; Romanov et al., 2014; Sullum et al., 2010; WHO, 2018b). Most researchers have previously reported that in the student population, regardless of the country of origin of the sample of respondents, overweight is represented on average by 18-22%, and obesity by 3-5% (ACHA, 2016, 2019; CDC, 2019; Rutkow et al., 2016; WHO, 2018c). In the sample, the percentage of respondents who have weight problems was significantly lower (6.3% overweight and 2.1% obese). These findings can also be explained by the nature of the material that the respondents studied during their time at university. Given that they were all enrolled in a study program with a large number of medical-health subjects, it is obvious that they had access to more information about healthy lifestyles than the average student (including information about nutrition and regular PA).

A comparative analysis of average values of PA levels revealed a significant negative impact of two months of inactivity. The energy expenditure in all three types of physical activities (light, moderate, and vigorous), and consequently the overall consumption, decreased significantly during the "isolation" period. Gallè et al. (2020) and Barkley et al. (2020) concluded that all sedentary behaviors significantly increased and all PA significantly decreased during the period of restraint. The largest decrease of 26.14% was recorded for

PA of the highest intensity (vigorous) as shown by other studies in which the decrease for this type of intensity ranged between 2.9 and 52.8 % (Ács et al., 2020; Barkley et al., 2020; Gallè et al., 2020; Gallo et al., 2020; Romero-Blanco et al., 2020; Sañudo et al., 2020; Alarcón Meza & Hall-López, 2021). The reduction for light PA was 15.65%, and the smallest was for moderate PA – 8.85%, which was significantly less than 30% (Gallo et al., 2020). This difference in the reduction of moderate PA can also be explained by the fact that the sample consisted of moderately active respondnets, whose activity trends remained relatively similar. The total PA index decreased during two months of inactivity by 17% which is different from the 28.6% (Ács et al., 2020) and 50% (Gallè et al., 2020) reductions. The decrease in total PA in the mentioned studies is significantly higher for several reasons: in our sample, a small decrease in moderate PA has already been explained, which as such affected the overall balance, a higher percentage of our female students spend time in Belgrade only during their studies, and during the ban on movement resided in environments where the restrictions were much milder and the third reason, unlike in other countries, in Serbia the lockdown measures were somewhat more relaxed.

Statistically significant differences were found only for vigorous activities and total weekly energy expenditure, while there were no significant differences in light and moderate PA.

Vigorous PA primarily involves sports and recreational activities that require leaving the house and going places where there is organized exercise (fitness centers, gym tracks, public parks, sports fields, swimming pools, etc.). As a state of emergency was introduced during the Covid-19 pandemic, which entailed limited freedom of movement, the closure of all sports and recreational facilities, and a ban on public gatherings, the scope of these most intensive activities was significantly reduced. On the other hand, light and moderate work was mostly related to household chores (cleaning, vacuuming, work in the garden or yard, etc.) and performing daily duties (going to work, shopping, etc.). The respondents had to perform this type of daily work during the "lockdown" period as well, which explains the absence of significant differences between light and moderate work. This shows that most people cannot meet the recommended health minimum of physical activity just by doing housework. The modern way of life, especially in urban areas, encourages hypokinesia in view of the proximity of commercial facilities for the supply and use of numerous technical aids in households that reduce energy expenditure to a minimum. In such living conditions, a modern man who cares about his health obviously has an increasing need for additional physical exercise.

Comparative analysis of the average values of variables for the assessment of morphological characteristics (body mass, BMI, body fat percentage, lean body mass and waist size) confirms the significant negative impact of two months of inactivity.

The average values of four of the five monitored body dimensions, which are taken as indicators of nutrition, increased statistically significantly. Body mass at the level of the complete sample increased on average by almost 1.5 kg, BMI by 0.5 kg/m^2, fat percentage in total body mass by 1%, and waist size by 1.4 cm. At the same time, lean body mass, which is used in anthropometry to estimate the share of muscle in the total body mass, decreased. It is an indirect indicator that the total muscle mass decreases during the absence of higher intensity PA.

The level of nutrition of the respondents was assessed using BMI, the values of which are aligned with the BMI values (21.77 kg/m^2) obtained in the study of Ghimire (2022). The frequency distribution showed that the sample was dominated by female students with a normal body weight. Both before and after the phase of inactivity, there were over 80% of them. The number of normally weighted respondents even increased (87.4%), which is a consequence of the increase in the body weight of three female students who were underweighted before the inactivity, and during the two-month experimental treatment they moved to the group with normal body weight. Although the overall changes were not statistically significant, these data indirectly point to the fact that resting for too long and the absence of more serious PA negatively affects a person's physical status. The number of obese, as well as overweight respondents, did not change during the inactivity experiment, which most affected the actuality that almost the same frequency distribution was obtained before and after two months of inactivity of the respondents. Therefore, despite the increase in body mass and the percentage of fat tissue, there was no serious deterioration in nutritional status. These data can be explained by the already mentioned fact that the research sample was formed by female respondents whose body composition and PA level (the condition for the sample is moderate physical activity) is above the average for the student population determined in previous research (CDC, 2019; WHO, 2018c; Ghimire et al. 2022).

CONCLUSION

A negative impact of limited freedom of movement on the estimated PA level was observed. It was found that the estimated PA level was significantly reduced, especially manifested through vigorous and total work. It was proven that insufficient movement caused deterioration of the monitored morphological features. The following were recorded and statistically confirmed: a significant increase in body mass, BMI, percentage of body fat and waist size, and a decrease in lean body mass.

Previous studies provide evidence of the benefits of exercise. The significance of this study is that, under changed circumstances, it was possible to prove, and it was proven, that a two-month period of inactivity produces negative consequences, and that previously reported sedentary behavior patterns of young people may later have implications for their overall health.

In this sense, it can be stated that this study also contributed to the confirmation of the negative impact of the pandemic caused by the SARS-CoV-2 virus on the lives of young people. This, among other things, speaks in favor of the general population observation that people's lifestyle during the pandemic period was predominantly focused on the close family circle, as well as virtual social life, and that physical activities and physical exercise experienced a significant reduction, and therefore more intensively highlighting the value of physical exercise and affirming outdoor activities should be one of the priority tasks of the kinesiology profession in the coming period.

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UTICAJ OGRANIČENOG KRETANJA TOKOM PANDEMIJE COVID-19 NA NIVO FIZIČKE AKTIVNOSTI I MORFOLOŠKE KARAKTERISTIKE

Cilj studije bio je utvrditi uticaj dvomesečne relativne motoričke neaktivnosti izazvane ograničenjem kretanja tokom perioda pandemije Covid-19 na promene nivoa fizičke aktivnosti i morfoloških karakteristika ispitanica. Istraživanje je sprovedeno na uzorku od 48 studentkinja starosti 20±0.6 godina. Podaci za odabrane varijable za procenu nivoa fizičkih aktivnosti i morfoloških karakteristika, prikupljeni su standardizovanim instrumentima u dve vremenske tačke. Uporedna analiza prosečnih vrednosti za procenu nivoa fizičke aktivnosti otkriva značajan negativan uticaj osmonedeljne relativne motoričke neaktivnosti. Energetska potrošnja u sva tri vida fizičkih aktivnosti (lak, umeren i težak rad), a posledično i ukupna potrošnja, iskazana u Metabolic Equivalent Task, značajno se smanjila tokom perioda neaktivnosti. Statistički značajne razlike utvrđene su samo za težak rad i ukupni rad tokom nedelje ($p < 0.001$), dok su kod lakih i umerenih fizičkih aktivnosti signifikantne razlike izostale. Analizom prosečnih vrednosti za procenu odabranih morfoloških varijabli dokazano je da je period neaktivnosti prouzrokovao pogoršanje morfoloških karakteristika. Kod svih pet praćenih telesnih dimenzija ispitanica dogodile su se statistički signifikantne negativne promene. Tokom eksperimentalnog tretmana neaktivnost (ETN) značajno su se povećali ($p < 0.001$): telesna masa, Body Mass Index (BMI), postotak telesne masti i obim struka. Istovremeno, bezmasna komponenta značajno se smanjila ($p = 0.007$).

Ključne reči: *Lockdown, relativna motorička neaktivnost, energetska potrošnja, telesni status*

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Research article

THE INFLUENCE OF MUSCLE MASS ON JUMP HEIGHT THROUGHOUT BIOLOGICAL MATURATION

UDC 796.012.527:159.922

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Abstract. *This study aims to investigate the influence of muscle mass on jump height based on the stage of biological maturation. The total sample consisted of 71 male athletes with three years of minimum training experience. The athletes were divided into three groups based on biological maturation: PrePHV, MidPHV, and PostPHV. Vertical jump height was assessed using three tests: the countermovement jump (CMJ), the countermovement jump with arm swing (CMJwas), and the squat jump (SJ). The results of the interaction between muscle mass percentage (MM) and peak height velocity (PHV) indicate that the effect of MM on vertical jump variables is greater in the PrePHV and MidPHV groups compared to the PostPHV group. For the PrePHV and MidPHV groups, there was a significant increase in CMJ [b=.83, t(22)=3.77, p=.001 and b=.92, t(14)=3.70, p=.002, respectively] and SJ [b=1.11, t(22)=4.45, p< .001 and b=1.06, t(14)=3.51, p=.003, respectively] when muscle mass percentage increased by one unit, while no significant increments were apparent for the PostPHV group [b=0.71, t=1.98, p=.058 and b=0.48, t(28)=1.65, p=.111, respectively]. Additionally, when muscle mass percentage increased by one unit, the CMJwas performance significantly increased in the PrePHV [b=1.48, t(22)=4.68, p<.001], MidPHV [b=1.15, t(14)=4.59, p<.001], and PostPHV [b=.97, t(28)=2.52, p=.018] groups. This study substantiates muscle mass as an important predictor of explosive power, demonstrating a more pronounced impact in the PrePHV and MidPHV relative to the PostPHV group. The study points out the importance of considering biological maturation when understanding the relationship between muscle mass and explosive power performance in young athletes.*

Key words: *regression, moderation effect, PHV, explosive power*

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INTRODUCTION

Biological maturation is one of the most critical factors influencing somatic growth and physical fitness, thus exerting a significant impact on the physical activity of adolescents (Malina, Bouchard, & Bar-Or, 2004; Sherar, Cumming, Eisenmann, Baxter-Jones, & Malina, 2010). Physiological adaptations occurring in the body over the years determine an individual’s biological maturity, which can differ from chronological maturity (Haibach, Reid, & Collier, 2011). Chronological maturity means the period that passes from an individual's birth and does not include the health status of a person's body (Prieto, Barbería, Ortega, & Magaña, 2005). Assessing biological maturity can be achieved through various methods, and evaluating peak height velocity (PHV) is a non-invasive method that finds extensive application in sports science (Malina, Bouchard, & Bar-Or, 2004). Assessment of PHV is performed based on anthropometric characteristics and age expressed in the decimal system (Mirwald, Baxter-Jones, Bailey, & Beunen, 2002). Maturity timing exerts a significant influence on results in motor ability tests due to considerable anthropometric and physiological differences related to the level of maturation. Athletes who are of older biological maturity achieve better results on tests of motor abilities and skills and they are usually taller than their peers (Coelho-e-Silva, Figueiredo, Carvalho, & Malina, 2008; Rađa, Erceg, & Milić, 2016). Static and explosive power develop rapidly after a growth spurt, and this is a period during which certain players distinguish themselves from their peers in terms of quality and talent (Te Wierike et al., 2014). Greater manifestation of power in accelerative athletes results from better-developed musculature, leading to dominance in motor skill execution and improved athletic performance (Avsiyevich, Plakhuta, & Fyodorov, 2016).

Adolescence is one of the most critical periods in the growth process, during which, under the influence of hormones, there is an increase in somatic characteristics, changes in body proportions, and body composition (Bodzsar & Zsaki, 2002). Rapid changes in body composition in boys manifest around the age of fourteen, and that change includes a reduction in body fat and an increase in the body mass index, which at this age reflects an increase in lean mass (Maynard, Wisemandle, Roche, Chumlea, Guo, & Siervogel, 2001; Malina, 2003). It has been proven that during adolescence, many high-intensity, short-duration anaerobic tasks, such as maximum running speed and jump height, improve (Philippaerts et al., 2006). These changes occur due to alterations in body composition, which influence the success of performing motor tasks that involve moving specific body parts or the whole body (Rađa, Erceg, & Grgantov, 2013). Generally, power development is accompanied by an increase in muscle mass, while an increase in aerobic endurance is often accompanied by a reduction in subcutaneous body fat (Stojiljković, Djordjević-Nikić, & Macura, 2005). Based on the aforementioned, it is known that biologically mature athletes tend to be more dominant in explosive power, and jump height improves due to changes in body composition, specifically an increase in muscle mass. This study represents an attempt to determine the extent of the influence of biological maturity and muscle mass on vertical jump performance, specifically to identify the stage of the PHV where the greatest impact of muscle mass on jump height is achieved. Therefore, the aim of this study was to investigate the influence of muscle mass on jump height based on the stage of biological maturation.

METHOD

The sample of participants

A total of 71 participants took part in this study, consisting of male subjects with a minimum training experience of three years. The athletes were divided into three groups based on biological maturity: PrePHV (N=27; chronological age=12.9±0.7; maturity age @ PHV=13.9±0.6; maturity offset=-1±0.4; body height=157.7±6,7), MidPHV (N=12; chronological age=12.9±0.5; maturity age @ PHV=12.9±0.5; maturity offset=-0.1±0.2; body height=169.3±3.9) and PostPHV (N=32; chronological age=14.8±0.9; maturity age @ PHV=13.1±0.7; maturity offset=1.6±0.8; body height=179.2±7.9). The participants voluntarily took part in the study, which was conducted following the Helsinki Declaration. Parental/guardian consent was obtained for all the participants since they were under the age of 18 at the time of the study. All procedures were approved by the Ethical Board of the Faculty of Sport and Physical Education, University of Niš.

The sample of variables

Anthropometric characteristics

Measurement of anthropometric characteristics was conducted by a physician following a predetermined procedure (Ross & Marfell-Jones, 1991) and included measuring body height, sitting height, and leg length using an anthropometer with a precision of 0.1 cm (Martin anthropometer). Body composition assessment was conducted using an electronic scale (Omron BF 511) and included the following values: body weight (kg), the body mass index (BMI), percentage of muscle mass (MM), and percentage of body fat (% fat).

Maturation Assessment

Maturation was calculated on the day of testing according to the formula established by Mirwald, Baxter-Jones, Bailey, and Beunen (2002). The division of participants into Pre-, Mid-, and Post-PHV groups was based on the Maturity Offset (years), which represents a value expressed in years as an indicator of how much time has passed since the PHV occurred.

BOYS: Maturity offset (years) = -9.236 + (0.0002708 × [Leg Length × Sitting Height]) + (-0.001663 × [Age × Leg Length]) + (0.007216 × [Age × Sitting Height]) + (0.02292 × [weight: height × 100])

The PrePHV group consisted of participants with a Maturity Offset value below -0.5. The Maturity Offset for the MidPHV group ranged from -0.49 to 0.49, while participants in the PostPHV group had a Maturity Offset value above 0.5 (Meyers, Oliver, Hughes, Lloyd, & Cronin, 2017).

Assessment of Explosive Power

Explosive power was tested using three vertical jump tests. Vertical jump performance was assessed using valid and reliable tests (Markovic, Dizdar, Jukic, & Cardinale, 2004): the countermovement jump (CMJ); the countermovement jump with arm swing (CMJwas); and the squat jump (SJ), which were executed following previously described protocols (Hara, Shibayama, Takeshita, Hay, & Fukashiro, 2008). An electric photoelectric cell system was used to determine the height of the executed jumps (Optojump, Microgate, Bolzano, Italy).

Sample Size Calculation

We conducted an a priori multiple regression power analysis using G*Power (Faul, Erdfelder, Buchner, & Lang, 2009) for the moderation analysis with five predictors (muscle mass percentage, MidPHV, PostPHV, and muscle mass percentage*MidPHV and muscle mass percentage*PostPHV interactions) as the input parameters. The given values of alpha (0.05), power (0.80), and expected small effect size (f = 0.20) were the parameters of choice for the sample size calculations. Based on these assumptions, the desired sample size for this study was 70 participants.

Statistical analyses

RStudio was used to process the data (version 2022.07.0.548, Spotted Wakerobin, Boston, MA). Descriptive statistics were produced for each power performance variable (CMJ, CMJA, and SJ). When applicable, means, medians, and standard deviations were estimated to characterize categorical and continuous variables for the whole sample. Multiple moderation models were employed to determine if PHV moderated the relationship between muscle mass percentage and power performance variables (the CMJ, CMJwas, and SJ). Based on Hayes's multi-categorical moderation analysis (model 1), the moderating effect was evaluated using a customized R script (Hayes, 2022). The QuantPsyc package is utilized to center variables and explore the interaction between muscle mass percentage and PHV on power performance variables, with muscle mass percentage and PHV as the dependent variables and the power performance variables as the independent variables. A bootstrapping approach was applied (with 5000 resamples). The threshold of significance was set at 0.05.

RESULTS

The data were checked for outliers and regression assumptions, and no violations were found. The QuantPsyc package was used to center variables and analyze the interaction between muscle mass percentage and PHV, predicting CMJ, CMJwas, and SJ performance.

Each regression model of the association between muscle percentage and power performance variables was significant (see Table 1). Tests of interactions of the highest unconditional order revealed that the moderating influence of muscle percentage was not significant for CMJ [$F(2,64) = 0.11$, $p = .899$], CMJwas [$F(2,64) = 0.11$, $p = .899$], and SJ [$F(2,64) = 1.55$, $p = .219$], and uniquely accounts for 0.0018, 0.0075, and 0.0318 % of the variance, respectively. Additionally, both muscle mass*MidPHV and muscle mass*PostPHV interactions were insignificant for CMJ, CMJwas, and SJ, respectively.

Table 1 Regression results using CMJm CMJwas, and SJ as the criterion

Predictor (CMJ)	b	*B* 95% CI [LL, UL]	*sr²*	*sr²* 95% CI [LL, UL]	Fit
(Intercept)	24.15**	[22.82, 25.61]			
MM	0.83*	[0.25, 1.26]	.04	[.00, .12]	
MidPHV	-0.08	[-2.16, 2.12]	.00	[.00, .02]	
PostPHV	5.61**	[2.71, 8.28]	.12	[.03, .26]	
MM*MidPHV	0.08	[-0.55, 0.91]	.00	[.00, .02]	R^2= .458**
MM*PostPHV	-0.13	[-1.11, 0.82]	.00	[.00, .06]	95% CI[.33, .63]
Predictor (CMJwas)	**b**	**B 95% CI [LL, UL]**	**sr²**	**sr² 95% CI [LL, UL]**	**Fit**
(Intercept)	30.53**	[28.91, 32.15]			
MM	1.48**	[0.78, 2.02]	.10	[.02, .21]	
MidPHV	-1.72	[-4.08, 0.47]	.01	[.00, .03]	
PostPHV	5.61**	[2.53, 8.83]	.08	[.02, .19]	
MM*MidPHV	-0.33	[-0.95, 0.61]	.00	[.00, .02]	R^2= .530**
MM*PostPHV	-0.51	[-1.53, 0.41]	.01	[.00, .06]	95% CI[.40, .69]
Predictor (SJ)	**b**	**B 95% CI [LL, UL]**	**sr²**	**sr² 95% CI [LL, UL]**	**Fit**
(Intercept)	24.28**	[22.92, 25.78]			
MM	1.11**	[0.70, 1.52]	.12	[.03, .24]	
MidPHV	-1.04	[-3.50, 1.29]	.00	[.00, .05]	
PostPHV	1.44	[-1.10, 4.12]	.01	[.00, .08]	
MM*MidPHV	-0.05	[-0.77, 0.73]	.00	[.00, .03]	R^2= .345**
MM*PostPHV	-0.63	[-1.48, 0.04]	.02	[.00, .12]	95% CI[.24, .55]

Note. A significant *b*-weight indicates that the semi-partial correlation is also significant, *B*-represents unstandardized regression weights, sr^2-represents the semi-partial correlation squared, *LL* and *UL*-indicate a confidence interval's lower and upper limits, respectively, *-indicates p < .05, **-indicates p < .01.

Nonetheless, it is evident from the estimate of muscle mass percentage and PHV interaction and the conditional effect that the effect of muscle mass percentage on power performance variables is larger for the PrePHV and MidPHV compared to the PostPHV group. For the PrePHP and MidPHV groups, there was a significant increase in CMJ [b=.83, t(22)=3.77, p=.001 and b=.92, t(14)=3.70, p=.002, respectively] and SJ [b=1.11, t(22)=4.45, p<.001 and b=1.06, t(14)=3.51, p=.003, respectively] when muscle mass percentage increased by one unit, while no significant increments were apparent for the PostPHV group [b=0.71, t=1.98, p=.058 and b=0.48, t(28)=1.65, p=.111, respectively]. Additionally, when muscle mass percentage increased by one unit, CMJwas performance significantly increased in the PrePHV [b=1.48, t(22)=4.68, p<.001], MidPHV [b=1.15, t(14)=4.59, p<.001], and PostPHV [b =.97, t(28)=2.52, p=.018] groups. Figure 1 shows the interaction between the predictors.

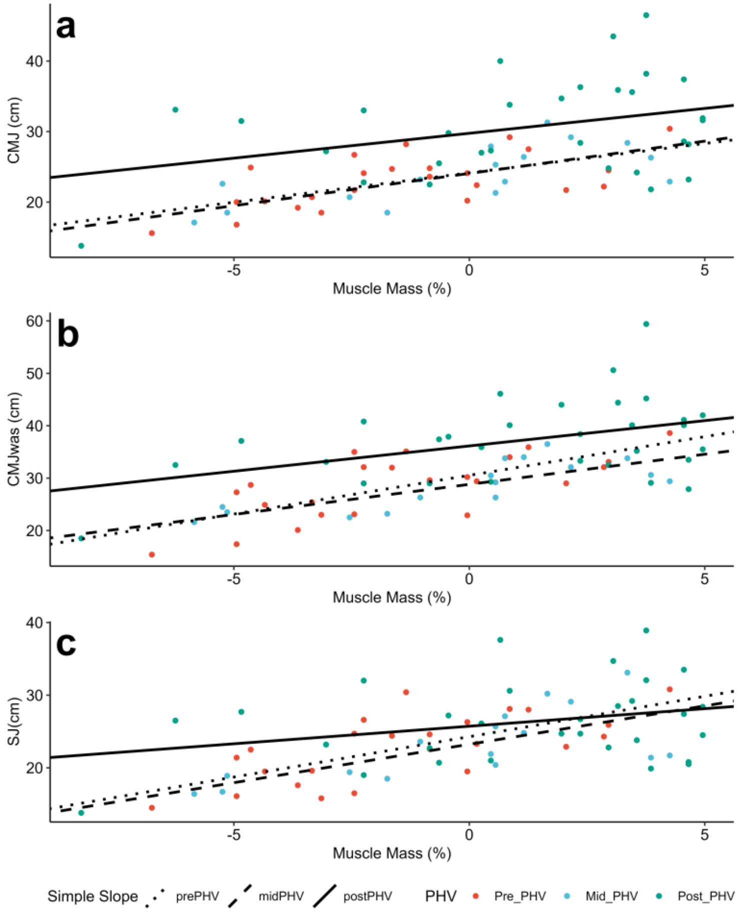

Fig. 1 Moderation plot of the relationship between muscle mass percentage (centered) and power performance variables (CMJ, CMJwas, and SJ) moderated by PHV. The dotted, dashed, and solid lines indicate PrePHV, MidPHV, and PostPHV simple slopes, respectively.

DISCUSSION

This study contributes to the literature by examining the interaction between muscle mass percentage and PHV throughout maturation in predicting explosive power variables. The results suggest that the relationship between muscle mass percentage and explosive power variables varies according to the maturation stage, with a significant impact observed in the PrePHV and MidPHV groups compared to the PostPHV group. Specifically, within the maturity stages, a unit increase in muscle mass percentage was associated with statistically significant CMJ and SJ performance enhancements. Conversely, in the PostPHV, the relationship between muscle mass percentage and jump performance did not reach statistical significance. It is important to underscore that, given the study's observational design, these relations do not imply causal relationships or longitudinal improvements. Instead, they reflect associations within a specific dataset, underscoring a potential link between muscle mass percentage and jump performance in varying maturity stages. Furthermore, this study showed a significant association between muscle mass percentage and CMJwas in all three PHV groups, with the most negligible impact observed in the PostPHV group. The performance technique of this jump should be considered, as the technique involves a coordinated action of legs and arms; thus, training significantly influences jump height. It is necessary to pay greater attention to training during this PHV stage in order to enhance explosive power performance in young athletes, as suggested by Meyers et al. (2017), who point out high neuromuscular focus and force development in relation to body weight as a critical factor.

Almeida-Neto et al. (2021) conducted a study to determine the extent to which muscle mass and biological maturation are strong predictors of power performance in athletes. On a sample of ninety-two athletes of both genders, they assessed biological maturation based on PHV and explosive power based on the vertical jump and CMJ. They concluded that biological maturation and muscle mass are somewhat uncertain predictors of jump height, as the correlation between these two variables and explosive power was not statistically significant for the girls, while it was statistically significant for the boys. Our study demonstrates that the interaction effect of PHV and muscle mass is significant in two stages of biological maturation. Results like this are expected because the improvement in jump height occurs during the adolescence period under the influence of changes in body composition (Rađa et al., 2013), a change that involves a decrease in body fat and an increase in muscle mass (Maynard et al., 2001; Malina, 2003).

The differences that occur in adolescents of the same chronological age is biological maturation and represent an essential factor affecting growth and power performance (Malina et al., 2004). Biologically mature adolescents exhibit anthropometric and physiological dominance compared to their peers, which leads to better power performance results (Coelho-e-Silva et al., 2008; Rađa et al., 2016). The study that examined the influence of maturation on explosive power performance indicates that participants in the PostPHV group achieved better results on explosive strength tests compared to the results of the PrePHV and MidPHV groups (Živković, Stojiljković, Trajković, Stojanović, Đošić, Antić, & Stanković, 2022). Another study by Silva et al. (2010) revealed that maturation significantly correlates with jumping performance in sports-involved adolescents, where biologically mature participants achieve better results than biologically immature counterparts. These are expected findings since it is known that explosive power develops during the PostPHV period, and this is the time when accelerants stand out from their peers in tests of motor ability (Te Wierike et al., 2014). The assumption is that these changes are the result of neural adaptations to training and hormonal shifts associated with pubertal development, which influence muscle mass and muscle strength (Falk & Eliakim, 2003; Faigenbaum, Lloyd, MacDonald, Myer, Citrin, 2016; Avsiyevich, Plakhuta, & Fyodorov, 2016).

A limitation of this study could be the method of bioelectrical impedance used to determine the percentage of muscle mass in the participants. The assumption is that using more sophisticated equipment than an electrical scale could obtain more precise data, although such an apparatus is unsuitable for field tests due to its size and calibration requirements. Another limitation is that the sample of participants comprised basketball, soccer, and handball adolescents. Certainly, it is better to direct research on a specific group (one sport), but to gather a larger number of athletes within this age group (PHV), the chosen approach for participant selection was the only feasible option.

CONCLUSION

In conclusion, this study provides further evidence for the importance of muscle mass in explosive power performance throughout maturation, with a greater impact observed in the PrePHV and MidPHV groups compared to the PostPHV group. Overall, the findings of this study align with previous research and underscore the importance of considering biological maturity in understanding the relationship between muscle mass and explosive power performance among young athletes. These findings have implications for training programs to enhance explosive power performance among young athletes and comprehend the mechanisms underlying puberty-related changes in physical performance. However, further research is needed to confirm these findings and better understand the complex relationship between muscle mass, maturation, and explosive power performance in athletes.

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UTICAJ MIŠIĆNE MASE NA VISINU SKOKA TOKOM BIOLOŠKE MATURACIJE

Cilj ovog istraživanja je ispitivanje uticaja mišićne mase na visinu skoka u zavisnosti od stadijuma biološke maturacije. Ukupan uzorak ispitanika sačinjen je od 71 sportiste, muškog pola, sa minimalnim trenažnim iskustvom od tri godine. Sportisti su podeljeni u tri grupe prema biološkoj zrelosti: PrePHV, MidPHV i PostPHV. Vertikalna skočnost je utvrđivana pomoću tri testa: skok iz stojećeg stava sa rukama na kukovima (CMJ), skok iz stojećeg stava sa zamahom rukama (CMJwas), skok iz polučučnja sa rukama na kukovima (SJ). Rezultati interakcije procenta mišićne mase (MM) i najvećeg prirasta visine (PHV) pokazuju da je efekat MM na varijable vertikalne skočnosti veći kod PrePHV i MidPHV poredeći ih sa PostPHV grupom. Za grupe PrePHP i MidPHV, značajno se povećava CMJ [b=.83, t(22)=3.77, p=.001 i b=.92, t(14)=3.70, p=.002] i SJ [b=1.11, t(22)=4.45, p<.001 i b=1.06, t(14)=3.51, p=.003] kada se procenat mišićne mase poveća za jednu jedinicu, dok se za PostPHV grupu ne povećava značajno [b=0,71, t=1,98, p=0,058 i b=0,48, t(28)=1,65, p=.111]. Pored toga, kada se procenat mišićne mase poveća za jednu jedinicu, CMJwas se značajno povećava u PrePHV [b=1,48, t(22)=4,68, p<.001], MidPHV [b=1,15, t(14)=4,59, p<.001] i PostPHV [b=.97, t(28)=2.52, p=.018] grupama. Ovo istraživanje pruža dodatne dokaze o važnosti mišićne mase u predikciji performansa eksplozivne snage tokom maturacije, sa većim uticajem u grupama PrePHV i MidPHV u poređenju sa grupom PostPHV. Rezultati istraživanja naglašavaju važnost razmatranja biološke zrelosti pri razumevanju odnosa između mišićne mase i performansi eksplozivne snage mladih sportista.

Ključne reči: *regresija, moderacijski efekat, PHV, eksplozivna snaga*

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Research article

THE RELATIONSHIP BETWEEN FUNCTIONAL MOVEMENT SCREEN SCORES AND SPORTS PERFORMANCE IN ELITE WOMEN'S SOCCER PLAYERS

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Abstract. *The aim of this study was to analyze the relationship between functional movement screen (FMS) individual scores and sports performance variables in elite women's soccer players. Twenty elite women's soccer players (age: 22.01 ± 3.64) took part in the study. Players were screened using the FMS protocol with seven movement patterns: deep overhead squat (DS), hurdle step left (HS L) and right (HS R), in-line lunge left (ILL L) and right (ILL R), shoulder mobility left (SM L) and right (SM R), active straight leg raise left (ASLR L) and right (ASLR R), trunk stability push-up (TSPU) and rotary stability (RS) and three tests of vertical jumps: the squat jump, countermovement jump and countermovement jump with arms, speed on the 20m and slalom and zig zag test. The results showed negative correlations between the 10m sprint and HSL L ($p < 0.001$, $r = 0.587$), HS R ($p < 0.001$, $r = 0.566$) and ASLR R ($p < 0.001$, $r = 0.667$) and between the Slalom test and ILL R ($p < 0.005$, $r = 0.461$) and ASLR L ($p < 0.005$, $r = 0.454$). This study found little evidence of the relationship between FMS results and predictors of sports performance in elite women's soccer players. Strength and conditioning coaches may use these indicators as an assessment of the weakness of certain movements or muscle imbalance as one of the methods for correcting certain segments of sports performance which can later help them achieve better results on the field.*

Key words: *football, female, vertical jump, change of direction*

INTRODUCTION

Soccer is an intense multi-directional and intermittent field sport (Emmonds, Nicholson, Begg, Jones, & Bissas, 2019). At an elite level, women soccer requires high technical ability, tactical awareness, and an exceptionally high level of physical conditioning (Mohr, Krustrup, Andersson, Kirkendal, & Bangsbo, 2008). In sports performance aspects there are

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many explosive actions such as sprinting, jumping, tackling and change of direction (CoD) that appear to influence the outcome of games (Mujika, Santisteban, Impellizzeri, & Castagna, 2009). The assessment of performance is frequently used to monitor the fitness levels of athletes and the long-term effects of the training process (Turner et al., 2011). In the specific case of soccer assessment, batteries include tests to measure linear speed, change-of-direction speed, aerobic capacity, anaerobic power, lower-body power, isokinetic strength, flexibility, and technical skills (Brink, Nederhof, Visscher, Schmikli, & Lemmink, 2010; Svensson, & Drust, 2005). In addition to a biomechanical movement analysis there is a lack of tests that evaluate the movement pattern, a functional movement screen (FMS) has been proposed as a battery test to simplify the assessment of movement patterns in daily sports practice (Kraus, Schütz, Taylor, & Doyscher, 2014).

Functional movement can be defined as the ability to produce and maintain balance between mobility and stability along the kinetic chain while performing fundamental patterns with accuracy and efficiency (Mills, Taunton, & Mills, 2005). Functional movement is vital to performance and sports-related skills, and consists of the interplay between muscular strength, stability, flexibility, and motor control (Mills et al., 2005). Furthermore, the T-test used to study CoD performance and FMS found a moderate relationship in recreationally-active individuals ($r = -0.383$ to -0.462) (Okada, Huxel, & Nesser, 2011). Greater flexibility as measured by the hurdle step, in-line lunge, and the active straight leg raise, related to slower change-of-direction speed, and poorer unilateral jump performance in female team sports athletes (Lockie et al., 2015). Male youth soccer players showed the influence of FMS scores on the squat jump ($p< 0.001$; $r = 0.66$) and reactive agility ($p< 0.001$; $r = -0.54$) and significant correlations were found (Lloyd et. at., 2015). Finally, the squat jump and hurdle step showed a relationship ($p< 0.001$; $r = 0.369$) among youth elite soccer players (Silva, Clemente, Camões, & Bezerra, 2017). In contrast, FMS scores and sprinting tests at 5m, 10, and 20m were tested in nine female athletes, and sprinting tests had no significant correlations with the FMS tests (Lockie et al., 2015). Parchmann and McBride (2011) confirm these results where no relationship was found between speed tests and FMS scores.

A review of the existing evidence relationship between FMS and sports performance reveals inconsistent findings (Mills et al., 2005; Okada et al., 2011; Parchmann, & McBride 2011; Lockie et al., 2015; Lloyd et at., 2015; Silva et al., 2017). Specifically, some research has documented significant relationships between FMS and CoD tests and FMS and vertical jumps tests (Mills et al., 2005; Okada et al., 2011; Lloyd et. at., 2015; Silva et al., 2017). In contrast, studies have reported no significant relationships between FMS and sprint tests (Parchmann, & McBride 2011; Lockie et al., 2015). Although there are studies involving both female athletes (Mills et al., 2005) and male young soccer players (Lloyd et. at., 2015), there is a lack of data documenting how and whether there is a relationship between FMS and sports performance in elite women's soccer players. Due to the need for effective movement patterns during sports performance in soccer, it was hypothesized that higher scores on the FMS would relate to better performance on the sport-specific tests. The aim of this study was to analyze the relationship between functional movement screen individual scores and sports performance variables in elite women's soccer players. This study will provide a preliminary investigation of whether there is value for coaches to use the FMS to monitor functional deficiencies in women's soccer players with a view to enhancing sports performance.

METHODS

Participants

Twenty elite women's soccer players (age: 22.01 ± 3.64; height: 166.52±5.64 cm; body weight: 58.42±9.59 kg; body mass index: 21.02±2.89) took part in the cross sectional study. Procedure and testing were at the start of the preparatory phase. Players who were recruited had at least 3 years of experience in playing in the highest rank of the competition; had a general training history (more than four times per week) in the previous 12 months. Players who were in the recovery phase from some form of acute or chronic injuries and players in the process of rehabilitation were excluded.

All of the football players were first informed about the study. The purpose and aim of the study were explained to them, along with any possible consequences. In addition, the players were also informed about the procedure and course of the testing itself. All the players and their guardians gave written consent for voluntary participation in the testing.

Procedures

Before testing, all players were familiarized with the testing procedures. Familiarization involved a verbal explanation and demonstration of each test by the same member of the research team. Height was measured using an anthropometer (Seca 220; Seca Corporation, Hamburg, Germany) to the nearest 0.1 cm, while body composition was measured using a digital Inbody 770 (Brewer et al., 2021) scale to the nearest 0.1 kg (InBody 770; Biospace Co. Ltd, Seoul, Korea). Body composition, the functional movement screen, and vertical jump tests were estimated in the morning hours (8 a.m.-11 a.m.). One day prior to body composition testing, the players had to adhere to a protocol which included a minimum of eight hours of not consuming food, caffeine, or alcohol until testing the following morning (Brewer et al., 2021). After body composition testing, the players did a standardized 10-minute warm-up which consisted of jogging and multi-way dynamic stretching was used for all players before testing. The players completed 3 trials of each vertical jump test, each separated by 3 minutes of passive standing rest. The best performance was recorded as the outcome measure. Speed and change of direction tests were done on the club's courts in the afternoon. Also, the same warm-up was done as for the explosive power tests.

Measurement

Anthropometry

Height and body weight were measured to the nearest 0.1cm using a Martin anthropometer (GPM in Switzerland), and to the nearest 0.1kg using a calibrated balance beam (Avery Ltd, Model 3306 ABV).

Body composition

The evaluation of body composition was carried out in an indoor facility using multifrequency bioelectrical impedance (Inbody 770; Biospace Co. Ltd, Seoul, Korea) as per Brewer et al. (2021), at frequencies of 1, 5, 50, 250, 500 and 1000 kHz under controlled temperature conditions of 23-28°C. The measuring instrument used a tetrapolar system of tactile electrodes with eight points (four are attached to the palm and thumb, and the remaining four to the feet), which independently measure the impedance of the arms, torso, and legs. Body composition measures that were measured include: body weight and the body mass index.

Functional movement screen

Players were screened using the functional movement screen protocol that comprised the following seven movement patterns: the deep overhead squat (DS), hurdle step left (HS L) and right (HS R), in-line lunge left (ILL L) and right (ILL R), shoulder mobility left (SM L) and right (SM R), active straight leg raise left (ASLR L) and right (ASLR R), trunk stability push-up (TSPU), and rotary stability (RS). Players were given three trials of each movement pattern, with each trial being scored by an experienced rater in real time on a 4-point scale according to the functional movement screen rater manual and previous research (Cook, et al., 2006). The total FMS score was used for comparisons, and could range from 0 to 21.

Vertical jumps (SJ, CMJ, CMJA)

Vertical jumps were assessed by using the squat and countermovement jumps. The squat jump (SJ) consisted of a standing position with knees flexed at 90°, hands on the waist. With no help from the upper limbs, the player should jump and extend the legs, falling in the same place. The players waited 3s in the squat position before each jump. The countermovement jump (CMJ) started in a standing position with hands on the waist, was realized with flexion of the legs and simultaneously with the jump, the legs would be extended and fall in the same place. While the CMJA jump procedure was the same as for the previous jump, only the hands were free during all the phases of the maximum jump. For each movement, three trials were executed, with a rest period of 30s between them. The SJ, CMJ, and CMJA were tested with an optical measurement system consisting of a transmitting and receiving bar (Optojump, Microgate, Bolzano, Italy). The outcome extracted in each trial was jump height (cm). For each measure, the highest jump was taken into consideration for data analysis. The validity and reliability of these tests have been confirmed in previous studies (Glatthorn, et al., 2011).

Speed (running 0-20m)

The running speed of the players was determined based on time at 10m and 20m using infrared timing gates, the 20m sprint effort with photocell gates (Microgate, Polifemo Radio Light, Bolzano, Italy) placed 0.4m above the ground, with an accuracy of 0.001s. The timer was automatically activated as the participants crossed the first gate at the starting line with split times at 10m. The players were instructed to run the 20m distance as quickly as possible from a standing start (crouched start position 0.5m behind the timing lights). Acceleration was evaluated using the time to cover the first 5m of the 20m test. The participants performed two trials with at least 3 minutes of rest between them. The best performance of the two tests was used for further analysis. The 20m sprint was previously used to estimate linear speed in a study by Mirkov, Nedeljkovic, Kukolj, Ugarkovic, & Jaric (2008).

The slalom test

The participants all started with both feet behind the starting line. Six cones were set up 2 m apart, the first cone 1 m away from the starting line. Every player stood still facing the starting line, feet apart and the cone between his legs. He started after the signal and ran from the first to second cones. The player at the second cone had to be passed on his right-hand side. The player continued to run as fast as possible constantly changing direction from right to left, until he reached the player standing by the last cone. After the last cone, the player made a 180° turn and went on running the slalom to the starting line (Sporis, Jukic, Milanovic, & Vucetic, 2010).

The zig-zag test

The zig-zag test consisted of four 5-m sections set out at 100° angles. All players started with both feet behind the starting line. Every player stood still facing the starting line, feet apart and the cone between his legs. He started after the signal and ran from the first cone. The player continued to run as fast as possible constantly changing direction from right to left, until he reached the player standing by the last cone and finish line (Little, & Williams, 2005).

Statistical analysis

The data were processed by the Statistical Package for Social Sciences SPSS (v26.0, SPSS Inc., Chicago, IL, USA). The Shapiro-Wilk test confirmed normality in all the measures for use of parametric analyses ($p \geq 0.05$). Descriptive statistics (mean ± standard deviation; 95% confidence intervals) provided a profile for each parameter. Spearman's correlation analysis computed relationships between the FMS and performance tests ($p \leq 0.05$). The correlation coefficient strength was designated as per Hopkins (Hopkins, W. G. (2014). A rho (ρ) value between 0 to 0.3, or 0 to -0.3, was small; 0.31 to 0.49, or -0.31 to -0.49, moderate; 0.5 to 0.69, or -0.5 to -0.69, large; 0.7 to 0.89, or -0.7 to -0.89, very large; and 0.9 to 1, or -0.9 to -1, near perfect for predicting relationships. Stepwise multiple regression analyses ($p \leq 0.05$) were conducted to determine which could best predict performance in a particular test.

RESULTS

The performance test data is shown in Table 1. The Shapiro-Wilk test (p = 0.077 - 0.200) indicated that this data was normally distributed, even with the different athletic backgrounds of the participants.

Table 1 Descriptive data (mean ± standard deviation; 90% confidence intervals [CI]) for sports performance tests

Tests	Mean±SD	95% CI
SJ	22.65 ± 3.51	21.01 - 24.29
CMJ	23.34 ± 3.32	21.78 - 24.89
CMJA	27.31 ± 4.04	25.41 - 29.2
Sprint 10m	2.09 ± 0.9	2.05 - 2.13
Sprint 20m	3.59 ± 0.19	3.05 - 3.68
Slalom	6.30 ± 0.26	6.18 - 6.42
Zig-zag	5.85 ± 0.28	5.72 - 5.98

Note: SJ: squat jump; CMJ: countermovement jump; CMJA: countermovement jump with arm.

Figure 1 displays the mean individual FMS scores. There were no differences in the rotary stability for either side of the body, so one score is shown.

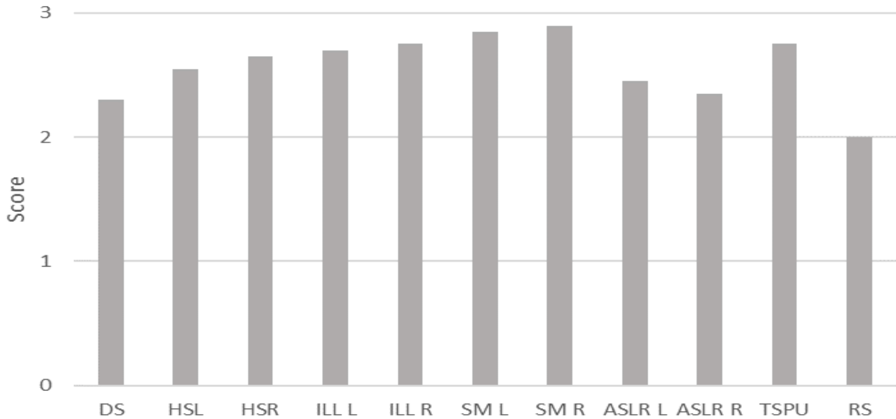

Fig. 1 Scores (mean ± standard deviation) for the Functional Movement Screen assessments (DS = deep squat, HS = hurdle step, ILL = in-line lung, SM = shoulder mobility, ASLR = active straight-leg rise, TSPU = trunk stability push-up, RS = rotary stability) for the left and right of the body in elite women's soccer players (n= 20).

Table 2 displays Spearman's correlations between the FMS and the sports performance tests. For the vertical jump test, the correlation is visible only on the CMJ test. The statistical correlation showed a positive value on the tests SM L ($p < 0.005$, $r = 0.535$) and TSPU ($p < 0.005$, $r = 0.491$). For the sprint tests, there were negative correlations between the 10m sprint and HSL L ($p < 0.001$, $r = 0.587$), HS R ($p < 0.001$, $r = 0.566$), and ASLR R ($p < 0.001$, $r = 0.667$). The Slalom test had a negative correlation with ILL R ($p < 0.005$, $r = 0.461$) and ASLR L ($p < 0.005$, $r = 0.454$).

Table 2 Spearman's correlations between Functional Movement Screen assessments for the left (L) and right (R) sides of the body, and sports performance tests in elite women's soccer players (n= 20).

	DS	HSL	HSR	ILL L	ILL R	SM L	SM R	ASLRL	ASLRR	TSPU	RS
SJ	0.350	0.209	0.164	-0.009	0.140	0.365	0.174	0.323	0.209	0.391	0.340
CMJ	0.303	0.105	0.036	-0.047	0.230	**0.535***	0.390	0.262	0.146	**0.491***	0.316
CMJA	0.294	0.288	0.327	-0.019	0.301	0.413	0.289	0.227	0.191	0.210	0.352
Sprint 10m	-0.342	**-0.587****	**-0.566****	-0.276	-0.050	0.098	0.073	-0.429	**-0.667****	-0.111	-0.024
Sprint 20m	-0.114	0.113	0.082	-0.114	-0.170	-0.061	-0.173	-0.375	-0.336	-0.250	-0.109
Slalom	-0.227	0.262	0.309	-0.341	**-0.461***	-0.316	-0.159	**-0.454***	0.009	-0.281	-0.243
Zig-zag	-0.312	0.270	0.155	-0.275	-0.090	-0.097	-0.159	-0.401	-0.036	0.090	-0.231

Note: SJ = squat jump; CMJ: countermovement jump; CMJA: countermovement jump with arm; DS = deep squat; HS = hurdle step; ILL = in-line lunge; SM = shoulder mobility; ASLR = active straight-leg raise; TSPU = trunk stability push-up; RS = rotary stability.

Only the TSPU, ASLL L and R, DS, and SM R produced significant predictive relationships on the performance tests (Table 3).

Table 3 Stepwise linear regression between Functional Movement Screen assessments for the left (L) and right (R) sides of the body, and sports performance tests

Best Predictors of the Tests	r	r^2	p
CMJ			
TSPU	0.499	0.249	0.025
Sprint 10m			
ASLR R	0.637	0.406	0.003
ASLR R - DS	0.786	0.618	0.000
Slalom			
ASLR L	0.457	0.208	0.043
Zig-zag			
SM R	0.467	0.218	0.038

Note: CMJ = countermovement jump; DS = deep squat; SM = shoulder mobility; ASLR = active straight-leg raise; TSPU = trunk stability push-up

Discussion

The aim of this study was to analyze the relationship between functional movement screen individual scores and sports performance variables in elite women's soccer players. The present results revealed that there is an association between individual parameters of the FMS test and sports performance assessment tests. For the sports performance evaluation tests, it was shown that the muscular stability as well as the mobility of certain joints is very significant and related to the achieved results on the tests. Specifically, the trunk stability push-up is the strongest predictor of performance for the vertical jump tests, while the active straight-leg raise test was the strongest predictor for the 10m sprint test and the slalom test. The performance of vertical jumps, CoD, and sprints can be influenced by factors such as strength and technique and thus may not easily predict deficiencies. Nevertheless, the range of motion required within the FMS actions does bear resemblance to those required in team sports movements (Minick, et al., 2010) and this study provides a preliminary analysis of whether FMS could identify deficiencies that may affect sports performance in elite women's soccer players.

The results showed the existence of a relationship between trunk stability push-up and CMJ ($p < 0.005$; $r = 0.491$). Lockie et al. (2015) obtained similar results for the vertical jump and trunk stability push-up in female athletes where the relationship was ($p < 0.005$ $r = 0.846$), while no relationship with the standing broad long jump was determined. In contrast, Parchmann and McBride (2011) indicated that no relationship was determined between the FMS score and vertical jump in golfer players. The trunk stability push-up involves the maintenance of a stable trunk, which should allow for force transition through the body into the upper extremities (Cook et al., 2006). A vertical jump requires a strong core, to allow the force generated by the legs to travel into the upper body (Butcher, et al., 2007), which is important for team sport athletes who need to use their arms when airborne (Walsh, Boehm, Butterfield, & Santhosam, 2007). The trunk stability push-up may provide an indication of core stability that could assist with between-leg balance in vertical jumping for females. The strongest predictor of vertical jump height in the CMJ test was the trunk stability push-up ($p < 0.025$; $r = 0.499$; $r^2 = 0.249$).

The 10m sprint showed a relationship between the hurdle step left ($p < 0.001$, $r = -0.587$) and right ($p < 0.001$, $r = -0.566$) and active straight-leg raise ($p < 0.001$, $r = -0.667$), while the strongest predictors of the 10m sprint were the deep squat ($p < 0.000$; $r = 0.786$; $r^2 = 0.618$) active straight-leg raise ($p < 0.003$; $r = 0.637$; $r^2 = 0.406$). Lockie et al. (2015) determined no relationship between FMS tests and the 5m, 10m and 20m sprint. Parchmann and McBride (2011) also determined that there was no relationship between the FMS score and the 10m sprint. The hurdle step is a movement that requires proper coordination and stability between the hips and torso during the stepping motion as well as single leg stance stability (Cook et al., 2006). A good score on the hurdle step test requires stance-leg stability of the ankle, knee, and hip as well as maximal closed-kinetic chain extension of the hip (Cook et al., 2006). The active straight leg raise test assesses active hamstring and gastroc-soleus flexibility while maintaining a stable pelvis and active extension of the opposite leg (Cook et al., 2006). The active straight leg raise test requires functional hamstring flexibility. However, each of these screens is performed slowly, from positions atypical to team sports (Lockie et al., 2015). In contrast Lockie et al. (2015) determined that greater flexibility, and by extension greater musculotendinous compliance, may compromise power-based activities such as sprinting. As an example, greater musculotendinous compliance has been linked to increased 20-m sprint time in track sprinters (Nelson, Driscoll, Landin, Young, & Schexnayder, 2005).

In the CoD tests, in addition to the importance of the active straight leg raise test results ($p < 0.005$, $r = -0.454$), a relationship with the results of the in-line lunge test ($p < 0.005$, $r = -0.461$) was also determined. Also, Lloyd et al. (2015) determined that there was a relationship between active straight leg raise test and in-line lunge gain statistical significance. In contrast to these results, Parchmann and McBride (2011) showed that there was no association between FMS scores and t-test agility. Our results are in contrast with the results of Lockie et al. (2015) who showed a positive a relationship between the in-line lunge and the active straight-leg raise test. For both the 505 and modified T-test, higher scores on the hurdle step, in-line lunge, active straight-leg raise, and rotary stability were related to slower change-of-direction speed test times (Lockie et al., 2015).

CONCLUSION

The results of the study found little evidence of a relationship between FMS results and sports performance in elite women’s soccer players. However, certain significant relationships and predictors were found. The results are partially in line with previous research that determined a small relationships between FMS results and sports performance. A characteristic of the FMS is that it is performed slowly, from positions atypical to soccer, and may lead us to believe that the movement patterns evaluated by the FMS are not important in sports performance. Although functional movement and functional performance are related, the FMS should not be considered as a test of performance or to predict sports performance. Strength and conditioning coaches may use these indicators as an assessment of the weakness of certain movements or muscle imbalance as one of the methods for correcting certain segments of sports performance which can later help them achieve better results on the field. Future studies should use the FMS score as an additional indicator of the athlete's condition. Existing studies look at young athletes and injury prediction using the FMS test, while more studies are needed that deal with professional athletes and their abilities.

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ODNOS IZMEĐU REZULTATA TESTA FUNKCIONALNOG KRETANJA I SPORTSKIH PERFORMANSI ELITNIH FUDBALERKI

Cilj ove studije je bio da se analizira odnos između individualnih rezultata funkcionalne pokretljivosti (FMS) i varijabli sportskih performansi kod elitnih fudbalerki. U istraživanju je učestvovalo dvadeset elitnih fudbalerki (starost: 22.01 ± 3.64). Sportistkinje su ispitivane FMS protokolom sa sedam obrazaca pokreta: duboki čučanj sa potiskom (DS), skip preko prepone levom (HS L) i desnom nogom (HS R), iskorak u liniji desnom (ILL L) i levom nogom (ILL R), pokretljivost ramenog zgloba leve (SM L) i desne ruke (SM R), aktivno podizanje opružene level noge (ASLR L) i desne (ASLR R), sklek - stabilnost trupa (TSPU) i rotirajuća stabilnost (RS) i tri testa vertikalnih skokova: skok iz čučnja (SJ), skok u kontra pokretu (CMJ) i skok u kontra pokretu sa rukama (CMJa), sprint na 20m, brzina na slalom i cik-cak testu. Rezultati su pokazali negativne korelacije između sprinta na 10 m i HSL L ($p \leq 0,001$, $r = 0,587$), HS R ($p \leq 0,001$, $r = 0,566$) i ASLR R ($p \leq 0,001$, $r = 0,667$) i između slalom testa i ILL R ($p \leq 0,005$, $r = 0,461$) i ASLR L ($p \leq 0,005$, $r = 0,454$). Ova studija je pokazala malu povezanost između rezultata FMS-a i prediktora sportskih performansi kod elitnih fudbalerki. Treneri snage i kondicije mogu koristiti ove indikatore kao procenu slabosti određenih pokreta ili mišićne neravnoteže kao jednu od metoda za korigovanje pojedinih segmenata sportskog učinka koji im kasnije mogu pomoći da ostvare bolje rezultate na terenu.

Ključne reči: *fudbal, žene, vertikalni skok, promena pravca*

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Research article

ADAPTIVE CHANGES IN BODY COMPOSITION UNDER THE INFLUENCE OF THE CORE BODY BALL PILATES TRAINING

UDC 796.012.1:613.71

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Abstract. *Body composition is a fitness component closely associated with health and the efficiency of sports performance, making it an integral aspect of research in sports medicine sciences. Implementing appropriate training programs results in suitable physiological adaptations and a notable enhancement in body composition. This study determined the effectiveness of a 10-week body core training conducted on a Pilates ball on the body composition of adolescent non-athletes. The sample of 48 respondents was randomly divided into an experimental (n=24) and a control group (n=24.) The experimental group performed the ball Pilates program twice a week during regular physical education classes, while the control group carried out a standard physical and health education program. The experimental program consisted of balanced sitting exercises, stabilization endurance exercises, and dynamic exercises on a Pilates ball to strengthen the trunk stabilizer muscles. Before the beginning and at the end of the experimental period, the absolute and relative values of the body fat mass and the absolute values of the skeletal muscle mass were measured in both groups of participants. Statistically significant improvements and moderate effects were determined in all body composition parameters within the experimental group when the final measurements were compared to the initial ones. In the control group of respondents, improvements were only numerical and did not reach statistical significance. At the final measurement, statistically significant differences and moderate effects of the experimental treatment in skeletal muscle and body fat mass were determined. The findings of the study confirm the effectiveness of core body training on a Pilates ball in enhancing the body composition of adolescent non-athletes.*

Key words: *effects, adolescents, lean body mass, fat body mass, core stability, Pilates ball*

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INTRODUCTION

Pilates on a ball is a conditioning and body-shaping method rooted in stretching and strengthening exercises designed to enhance body posture, joint health, and core stability and mobility. The core, or the body's center, encompasses the musculoskeletal structures comprising the lumbo-pelvic-hip complex (LPHC) and the muscles that connect the pelvis to the upper and lower extremities (Clark, Lucett, McGill, Montel, & Sutton, 2018). Core muscles play a pivotal role in stabilizing the LPH complex and transmitting force from the core to the extremities, ultimately enhancing neuromuscular efficiency throughout the entire kinetic chain's system of motion (Gurtner, 2014). This is why their development is crucial and integral to most training programs.

Core training encompasses exercises performed in different training zones, leading to physiological adaptations in various body tissues. As exercise intensity and volume progress throughout the training period, Pilates ball training includes exercises in low (60–70% of maximum heart rate [HRmax], moderate (70–80% of HRmax), and high-intensity zones (80-90% of HRmax)), especially when performing more complex plank exercises. During aerobic exercise in the low and moderate-intensity zones, which dominate during warm-up and dynamic exercises on the Pilates ball, energy is sourced from the combustion of glucose and free fatty acids. Stabilization endurance exercises, such as plank exercises, prevent the loss of lean body mass resulting from physical inactivity and effectively enhance the muscular tone of the entire body, particularly the core muscles. Numerous studies have demonstrated that regular engagement in plank exercises significantly increases lean body mass (Buttichak, Leelayuwat, Bumrerrajand, & Boonprakob, 2019; Raj & Pramod, 2012; Ružić, 2020) while notably reducing body fat mass (Anant & Venugopal 2021; Buttichak et al., 2019; Cakmakçi, 2011; Prakash, James, Sivakumar, & Dharini, 2021; Raj & Pramod, 2012; Ružić, 2020; Srinivasulu & Amudhan, 2018; Welling & Nitsure, 2015; Wrotniak, Whalen, Forsyth, & Taylor, 2001). Although the established decrease in body fat mass can generally be attributed to increased oxidation of fatty acids during exercise in the low to moderate intensity zone, the application of plank exercises is also associated with a tendency to decrease the fat component of body composition and increase the basal metabolic rate (Park, Lee, Heo, & Jee, 2021).

Maintaining an optimal level of fat and lean components of the body is vital for a healthy body composition and, thus, for the overall health form of an individual (Ayers & Sariscsany, 2010). On average, the fat-to-muscle mass ratio in females is 28:39%, and in men 18:42% (Pavlica & Rakić, 2019, p. 80). Increased values of body fat mass are highly correlated with increased cardiovascular morbidity and mortality, type 2 diabetes, and lipid and lipoprotein disorders (Badimon, Padró, & Vilahur, 2012; Heyward & Wagner, 2004; Pavlica & Rakić, 2019). In addition, studies indicate health consequences due to low lean body mass values, especially in physically inactive and obese people. A four times increased prevalence of cardiometabolic diseases such as dyslipidemia, cardiovascular disease, and type 2 diabetes was found in persons with low compared to persons with lean body mass reference values (Khazem et al., 2018). Decreased muscle mass values are also closely related to decreased physical functions and quality of life and are considered significant predictors of morbidity and mortality (Pavlica & Rakić, 2019; Prado et al., 2018).

In addition to physical activity, physiological adaptations in body composition are conditioned by numerous endogenous and exogenous factors, such as genetic factors, lifestyle, gender, age, caloric intake, food quality, sleep quality, stress, and other factors. Generally, regular physical activity with proper nutrition is considered a dominant factor determining body composition (Welling & Nitsure, 2015; Wrotniak et al., 2001). An optimal dosage of training stimuli, such as frequency, duration and intensity of applied exercises according to the exercisers' initial fitness and age, is very important (Jakičić et al., 2001). According to Olson et al. (2004), the minimum exercise duration to burn fat should not be less than 30 minutes.

Although some studies show that an 8-week period with a frequency of two training sessions per week lasting for 45-60 minutes is an adequate training stimulus for causing adaptive changes in body composition in obese children and adolescents (Wrotniak et al., 2001), most studies show that high frequency of training sessions is required for achieving similar training effects (Anant & Venugopal, 2021; Cakmakçi, 2011; Prakash et al., 2021; Vispute, Smith, LeCheminant, & Hurley, 2011; Welling & Nitsure, 2015) or longer duration of the training period (Buttichak et al., 2019; Khajehlandi & Mohammadi, 2021; Prakash et al., 2021; Raj & Pramod, 2012; Srinivasulu & Amudhan, 2018). At the same time, it should be considered that the increase in bone density and quality depends on nutrition to a significant extent.

In contrast to most studies, some research findings challenge the effectiveness of Pilates ball exercises in inducing adaptive changes in body composition (Vispute et al., 2011; Yaprak, 2018; Yaprak & Küçükkubaş 2020). Such results often stem from insufficiently addressing the components of training, encompassing frequency, intensity, duration, and the selection of training activities (Segal, Hein, & Basford, 2004). It is worth noting that individuals with a normal weight tend to experience slower weight loss than those who are overfed or obese (Jakicic et al., 2001).

Given the observed disparities in the results of various studies, there is a need for further research to provide a more comprehensive understanding of this issue. The primary objective of this study is to investigate the effect of core body training on a Pilates ball on the adaptive changes in the body composition of young adolescent non-athletes.

METHOD

The sample of participants

The sample of participants consisted of 48 clinically healthy female adolescents, first-grade high school students from Niš. The participants attended only regular physical and health education classes at school, prescribed by the Institute for the Advancement of Education and Upbringing of the Republic of Serbia. They were not additionally involved in any training activities for the previous six months.

Following a comprehensive introduction outlining the objectives and concept of this longitudinal research, which received approval from the Ethics Committee of the Faculty of Sport and Physical Education in Niš, the participants willingly provided their parents' written consent to participate in the study. To uphold ethical standards, the study maintained the anonymity of the participants, following the guidelines for clinical research outlined in the World Medical Association's Declaration of Helsinki (WMA, 2013). Statistical data analysis was based on the test results of the participants who did not exceed a 10% absence rate during the experimental period.

The participants were randomly assigned to either the experimental or control group, with each group consisting of 24 participants (Table 1).

Table 1 Basic anthropometric characteristics of the experimental and control group of participants (mean values ± standard deviation)

Respondents	N	A	BH (cm)	BM (kg)	BMI (kg/m^2)
EG	24	15.28 ± 0.48	162.76 ± 2.33	56.77 ± 4.08	21.43 ± 1.10
CG	24	15.06 ± 0.29	163.13 ± 2.25	54.04 ± 4.77	20.68 ± 1.54

Legend: N - number of participants; A - age (years);
BH - body height; BM - body mass; BMI - body mass index.

The sample of measuring instruments

The anthropometric characteristics of the experimental and control group of participants were determined by measuring body height, body mass and the body mass index. All measurements were carried out according to the recommendations of the International Biological Program - IBP (Weiner & Lourie, 1981).

Body height was measured using the Martin anthropometer, which measures with an accuracy of 0.1 cm. Body mass and the body mass index were measured using the body structure analyzer "Inbody 720" (Inbody 720, Tetrapolar; 8-Point Tactile Electrode System - Biospace Co. Ltd). Using the most precise methods, the body structure analyzer segmentally analyzed and determined the following body composition parameters: skeletal muscle mass (kg), body fat mass (kg) and body fat percentage (%).

The initial and final measurements of anthropometric characteristics and body composition parameters were carried out in the morning by previously trained measurers. Both measurements were carried out using the same measuring instruments and techniques. During the measurements, the participants were minimally dressed and barefoot. The participants were told not to engage in strenuous exercise for at least two days before the measurement and not to consume food or drink for three hours before the measurement.

Experimental design

The experiment was conducted in regular physical and health education classes twice a week for 45 minutes. The experimental group carried out a ball Pilates program to strengthen the muscles of the body core (Table 2) and the control group a standard physical and health education program.

The physical education classes for the control group of participant followed a traditional four-part structure, comprising an introductory (3-5 min), preparatory (8-10 min), main (25-30 min) and final phase (5 min). The participants engaged in physiological warm-up activities in the introductory phase, primarily running. The preparatory phase involved a variety of shaping exercises, some utilizing props and others not. During the main phase of the class, the regular physical education curriculum was delivered, covering topics such as volleyball, track and field, and artistic gymnastics. The final phase of the class focused on static stretching exercises targeting all major muscle groups.

The training sessions of the experimental group of participants consisted of: a) a standard warm-up, applying jogging and dynamic stretching exercises (10 minutes); b) a ball Pilates exercise program to strengthen the body's core muscles (30 minutes); and c) a five-minute cool-down using static stretching exercises with an emphasis on stretching the core muscles. The basis of the ball Pilates program was endurance exercises on the Pilates ball and trunk flexion, extension, and rotation dynamic exercises (Table 4). The periodization of ball Pilates training was carried out through three phases, according to the guidelines taken from Clark, Lucett, McGill, Montel, & Sutton (2018):

1. the Phase of Neural-Adaptation, aimed at establishing motor control using one-dimensional exercises. In this phase, the participants performed exercises to develop static stability of the body core, and the flexion, extension, and trunk rotation exercises necessary to improve the functional training outcomes;
2. the Developmental Phase of Accumulation, aimed at improving the dynamic stability of the trunk stabilizers by applying more complex and more intense exercises;
3. the Advanced Phase of Specialization, aimed at increasing the force production of trunk stabilizers by applying structurally more complex and more energy-demanding exercises.

Table 2 Experimental program

Phase 1 / Week 1 /Pace: Slow				Phase 1 / Week 2 /Pace: Slow			
Exercises	S	REP	Time (s)	Exercises	S	REP	Time (s)
Balanced Sitting	1	/	:60 el	Balanced Sitting	1	/	:60 el
Ball Prone Bridge	2	/	:60	Ball Prone Bridge	3	/	:45
Ball Side Bridge	2	/	:60 es	Ball Side Bridge	3	/	:45 es
Ball Supine Bridge	2	/	:60	Ball Supine Bridge	3	/	:45
Ball Forward Bend	3	10	/	Ball Reverse Crunch	3	10	/
Ball Trunk Hyperextension	3	10	/	Ball Reverse Hyperextension	3	10	/
Ball Supine Hip Rotation	2	8	/	Ball Supine Hip Rotation	3	8	/
Phase 1 / Week 3/Pace: Slow				Phase 2/ Week 4/Pace: Medium			
Exercises	S S	REP	Time (s)	Exercises	S	REP	Time (s)
Balanced Sitting	2	/	:45 el	Balanced Sitting – one leg off	1	/	:60
Ball Prone Bridge	3	/	60	Single-Leg Ball Prone Bridge	2	/	:35 el
Ball Side Bridge	3	/	:60 es	Ball Side Bridge - upper leg up	2	/	:30 es
Ball Supine Bridge	33 3	/	:60 es	Ball Supine Bridge- one leg up	2	/	:30 el
Ball Forward Bend	2	10	/	Ball V-Pass	3	10	/
Ball Reverse Crunch	2	10	/	Ball Lateral Crunch	2	8 es	/
Ball Trunk Hyperextension	2	10	/	Ball Diagonal Crunch	2	8 es	/
Ball Reverse Hyperextension	2	10	/	Superman on a Ball Exercise	2	8	/
Ball Supine Hip Rotation	3	8-10	/	Ball Single-leg Hip Rotation	1	10 el	/
Phase 2 Week 5 /Pace: Medium				Phase 2 Week 6 /Pace: Medium			
Exercises	S	REP	Time (s)	Exercises	S	REP	Time (s)
Balanced Sitting – one leg off	2	/	:40 el	Balanced Sitting – one leg off	3	/	:30
Ball Single Leg Prone Bridge	2	/	:40 el	Ball Single Leg Prone Bridge	3	/	:30
Ball Side Bridge - upper leg up	2	/	:40 es	Ball Side Bridge - upper leg up	3	/	:30 es
Ball Supine Bridge - one leg up	2	/	:40 el	Ball Supine Bridge - one leg up	3	/	:30 el
Ball Pike	1	6	/	Ball Pike	1	10	/
Ball Lateral Crunch	2	10 es	/	Ball Lateral Crunch	3	8 es	/
Ball Diagonal Crunch	2	10 es	/	Ball Diagonal Crunch	3	8 es	/
Superman on a Ball Exercise	2	10	/	Superman on a Ball Exercise	2	12	/
Ball Single-leg Hip Rotation	2	7 el	/	Ball Single-leg Hip Rotation	2	10 el	/
Phase 2/ Week 7/Pace: Medium				Phase 3 / Week 8 /Pace: Medium			
Exercises	S	REP	Time (s)	Exercises	S	REP	Time (s)
Balanced Sitting – one leg off	3	/	:35	Ball 4-point Kneeling	2	/	:30
Ball Single Leg Prone Bridge	2	/	:50 el	Ball Forearm Plank	3	/	:30
Ball Side Bridge - upper leg up	2 es	/	:50 el	Ball Side Plank – elbow on ball	3 es	/	:30 es
Ball Supine Bridge - one leg up	2	/	:50 el	Ball Supine Bridge - one leg up	3	/	:35 el
Ball Pike	2	6	/	Ball Pike	2	8	/
Ball Lateral Crunch	3	10 es	/	Ball Lateral Crunch	3	12 es	/
Ball Diagonal Crunch	3	10 es	/	Ball Diagonal Crunch	3	12 es	/
Superman on a Ball Exercise	3	10	/	Superman on a Ball Exercise	3	10	/
Ball Single-leg Hip Rotation	3	8 el	/	Ball Single-leg Hip Rotation	3	10 el	/
Phase 3 / Week 9 /Pace: Medium				Phase 3/ Week 10 /Pace: Medium			
Exercises	S	REP	Time (s)	Exercises	S	REP	Time (s)
Ball 4-point Kneeling	2	/	:45	Ball 4-point Kneeling	1	/	:25
Ball Forearm Plank	3	/	:45	Ball Forearm Plank	2	/	:30
Ball Side Plank – elbow on ball	3 es	/	:45 es	Ball Side Bridge - upper leg up	3 es	/	:45 es
Ball Supine Bridge - one leg up	3	/	:45 el	Ball Supine Bridge - one leg up	3	/	:50 el
Ball Pike	2	10	/	Ball V-Pass	3	15	/
Ball Lateral Crunch	3	15 es	/	Pike	3	8	/
Ball Diagonal Crunch	3	15	/	Superman on a Ball Exercise	3	15	/
Superman on a Ball Exercise	3	12 es	/	Ball Hip Rotation	3	10 es	/
Dumbbell Russian Twist	3	10 es	/	Ball Diagonal Crunch	3	10-12 es	/
Ball Single-leg Hip Rotation	3	12 es	/	Ball Side Crunch	3	15 el	/

Legend: el - with each leg; es - on both sides; REP - the number of repetitions; S -the number of sets.

Statistical Analysis

The software package for social sciences, SPSS Statistics, version 23.0, was used for statistical data processing. The level of statistical significance was set at $p<0.05$.

Basic descriptive parameters were calculated for all the sample characteristics and body composition variables. Due to the relatively small sample of participants, the normality of data distribution was checked using the Shapiro-Wilk test (Marques de Sà, 2007).

Differences in body composition between the groups at the initial and final measurements were examined using the t-test for independent samples. To determine differences within the experimental and within the control group between the initial and final measurements, the t-test for dependent samples was used.

The effect size was estimated using the partial eta-squared (η^2p), whose values, according to Ferguson (2009), denote small effects when $0.05\leq\eta2p< 0.26$, medium effects when $0.26\leq\eta^2p<0.64$ and large effects when $0.64\leq\eta^2p$.

RESULTS

Table 3 Descriptive body composition parameters of the experimental and control groups at the initial and final measurement

		Experimental group			Control group		
	Parameter	Mean	SD	S-W	Mean	SD	S-W
IM	SMMi (kg)	22.08	3.86	.584	22.74	3.22	.588
	BFMi (kg)	17.23	4.29	.569	18.59	4.70	.591
	BFPi (%)	30.35	5.08	.772	32.38	4.96	.534
FM	SMMf (kg)	23.98	3.93	.687	23.44	3.85	.604
	BFMf (kg)	15.32	4.52	.559	17.89	4.52	.665
	BFPf (%)	27.83	5.66	.790	31.72	4.64	.586

Legend: IM - initial measurement; FM - final measurement; SMMi - skeletal muscle mass; BFM - body fat mass; BFP- body fat percentage; Mean - mean value; SD - standard deviation; S-W - the significance of Shapiro-Wilk coefficient.

Table 3 indicates the descriptive data of the body composition of the experimental and control group at the initial and final measurements. For each body composition parameter, the following parameters were calculated: mean value, standard deviation and normality indicators of results distribution *(S-W).*

At the initial and final measurement, the Shapiro-Wilk test of the skeletal muscle mass, body fat mass in kilograms and percentages did not show a significant deviation from normal distribution (*S-W* > 0.05).

Given that the distribution of the results of the body composition parameters did not significantly deviate from normal distribution in either group either at the initial or at the final measurement, one of the conditions for applying parametric statistical tests for body composition data was fulfilled.

Table 4 Differences in body composition between the experimental and control group at the initial measurement

Parameter	Group	Mean	SD	t	p	η^2_p
SMMi (kg)	EG	22.08	2.86	-0.117	0.907	0.00
	CG	22.74	2.82			
BFMi (kg)	EG	17.23	4.29	0.023	0.982	0.00
	CG	18.59	4.30			
PBFi (%)	EG	30.35	6.48	0.038	0.314	0.01
	CG	32.38	4.76			

Legend: SMM - skeletal muscle mass; BFM - body fat mass; PBF - body fat percentage; EG - experimental group; CG-control group; Mean - mean value SD - standard deviation; t - value of t-test coefficient; p - coefficient of significance of t-statistics; η^2_p - partial squared eta (measure of effect size).

The coefficients of statistical significance of the t-test for independent samples (Table 4) showed that the experimental and control group did not differ statistically significantly in any body composition parameter at the initial measurement.

Table 5 Differences in body composition between the initial and final measurements of the experimental group

Parameter	Group	Mean	SD	t	p	η^2_p
SMM (kg)	IM	22.08	2.86	7.078	0.042*	.522
	FM	23.98	1.93			
BFM (kg)	IM	17.23	4.29	-8.507	0.047*	.610
	FM	15.32	4.52			
BFP (%)	IM	30.35	6.48	-7.249	0.039*	.545
	FM	27.83	6.66			

Legend: SMM - skeletal muscle mass; BFM - body fat mass; BFP - body fat percentage; IM - initial measurement; FM- final measurement; Mean - mean value; SD - standard deviation; t - the value of the coefficient (statistics) of the t-test; p - coefficient of significance; t - statistics; η^2_p - partial squared eta (measure of effect size); * - statistical significance at the level of p<.05.

Table 5 indicates the results of the univariate differences between the initial and final measurements of the experimental group in the body composition parameters.

Upon reviewing the t-test results for dependent samples, it becomes evident that there are statistically significant differences in the body composition between the initial and final measurements of the experimental group ($t_{SMM} = 7.078$, $p < .05$; $t_{BFM} = -8.507$, $p < .05$; $t_{BFP} = -7.249$, $p < .05$).

The partial squared eta coefficient values suggest medium effects in the skeletal muscle mass ($\eta^2p=.522$), body fat mass in kilograms ($\eta2p=.610$) and body fat percentage ($\eta^2p=.545$).

Table 6 Differences in body composition between the initial and final measurements of the control group

Parameter	Measurement	Mean	SD	t	p	η^2p
SMM (kg)	IM	22.74	1.83	- 0.117	.052	.232
	FM	23.44	1.85			
BFM (kg)	IM	18.59	4.30	- 0.122	.057	.235
	FM	17.89	4.33			
BFP (%)	IM	32.38	5.76	- 0.097	.059	.228
	FM	31.72	5.79			

Legend: SMM - skeletal muscle mass; BFM - body fat mass; BFP - body fat percentage; IM - initial measurement; FM- final measurement; Mean - mean value SD - standard deviation; t - the value of the t-test coefficient (statistics); p - coefficient of significance of t - statistics; η^2_p - partial squared eta (measure of effect size).

The t-test results for dependent samples (Table 6) indicate no statistically significant differences in mean values of the body composition parameters between the initial and final measurements of the control group (t_{SMM} = - 0.117, p > .05; t_{BFM} = - 0.122, p > .05; t_{BFP} = - 0.097, p > .05). The effects size measures indicate small effects in the skeletal muscle mass (η^2p = .232), body fat mass η2p = .235) and body fat percentage (η^2p = .228).

Table 7 Differences in body composition between the experimental and control group at the final measurement

Parameter	Group	Mean	SD	t	p	η2p
SMM (kg)	EG	23.98	1.93	5.220	0.00**	.497
	CG	23.44	1.85			
BFM (kg)	EG	15.32	4.52	-6.180	0.00**	.526
	CG	17.89	4.10			
BFP (%)	EG	27.83	5.66	-5.623	0.00**	.513
	CG	31.72	4.05			

Legend: SMM - skeletal muscle body mass; BFM - body fat mass; BFP - body fat percentage; E - experimental group; K-control group; Mean - arithmetic mean; SD - standard deviation; t - value of t-test coefficient; p - coefficient of significance of t-statistics; η^2_p - partial squared eta (measure of effect size); ** - statistical significance at the level of .01.

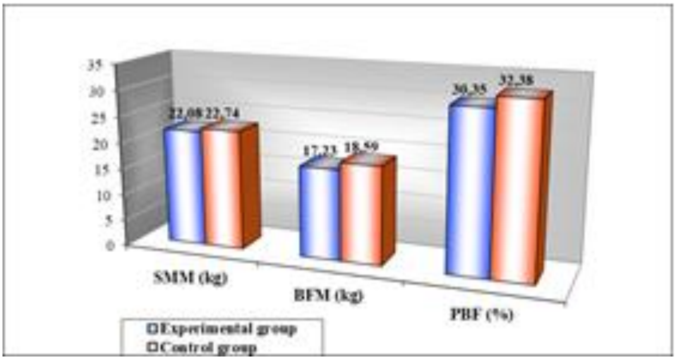
At the final measurement, the t-test for independent samples (Table 7) indicated that the groups of participants differed statistically significantly in all body composition parameters (t_{SMM}= 5.220, p <.01; t_{BFM}= - 6.180, p <.01; t_{BFP}= -5.623, p <.01) in favor of better results in the experimental group. The medium effects of the applied experimental treatment in skeletal muscle mass (η^2_p = .497), and body fat mass in kilograms (η^2_p =. 526) and percentages (η^2_p = .513) were determined.

DISCUSSION

This study aimed to compare the effectiveness of an experimental Pilates ball program and a standard Physical Education program in inducing adaptive changes in the body composition of young female adolescents. The experimental program included static and dynamic exercises on a Pilates ball, primarily focusing on strengthening the core muscles, while the standard program comprised volleyball, track and field and artistic gymnastics activities.

The findings demonstrated that the experimental program significantly improved all body composition parameters, whereas the standard program resulted in numerical improvements that did not reach statistical significance. Furthermore, at the final measurement, the experimental program exhibited significantly greater effects on enhancing body composition parameters than the standard Physical Education program.

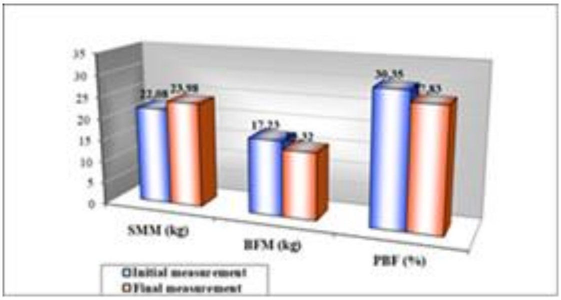
Before commencing the experiment, it was established that the groups of participants did not exhibit statistically significant differences in any body composition parameter (Graph 1). Only on a numerical level were slightly higher average values of all body composition parameters observed in the control group compared to the experimental group.



Graph 1 Intergroup differences in body composition at the initial measurement

According to McCarthy, Samani-Radia, Jebb, and Prentice (2013), the average values of skeletal muscle mass in both groups of participants were within the reference values for age and gender. However, according to Ayers and Sariscsany (2010), the average body fat mass of the control group of participants slightly increased, while the experimental group were at the upper limit of reference values. Other studies involving non-athlete participants also observed increased body fat mass values at the initial measurement (Buttichak et al., 2019; Cakmakçi, 2011; Lee, Kim, &, Lee, 2016; Vispute et al., 2011). On the contrary, lower initial body fat values than in this study were registered in studies that involved athletes (Aksen-Cengizhan, Onay, Sever, & Doğan, 2018; Anant & Venugopalb, 2021; Srinivasulu & Amudhan, 2018; Yaprak, 2018).

After the 10-week experimental period, significant improvements and moderate effects resulting from the applied experimental program were observed. These improvements were associated with an increase in skeletal muscle mass (t_{SMM}= 7.078, $p < .05$, $\eta^2 p$= .522) and a reduction in body fat mass, both in terms of absolute values (t_{BFM}= -8.507, $p < .05$, $\eta^2 p$ = .61) and the relative ones. (t_{PBF} = 7.249, $p < .05$, $\eta^2 p$= .545). The Pilates ball exercises, in conjunction with appropriate load progression throughout the experimental period, led to substantial adaptations in the experimental group's skeletal muscle mass and body fat mass (Graph 2).



Graph 2 Differences in body composition between the initial and final measurements of the experimental group

In addition to the training process, skeletal muscle mass values increase physiologically along with the increase in body height and, to a lesser extent, with the increase in body mass (Forbes, 1987; McCarthy et al., 2014) Plank exercises, which engage the whole body's musculature and not only the body core, have greatly contributed to the established adaptations of the skeletal muscle mass, increasing muscle mass even in a relatively short period (Akuthota, Ferreiro, Moore, & Fredericson, 2008; Behm, Drinkwater, Willardson, & Cowley, 2010; Park et al., 2021; Park & Park, 2019).

The obtained results align with other studies in which the participants significantly increased lean body mass (Anant &Venugopal, 2021; Buttichak et al., 2019; Raj & Pramod, 2012) and reduced body fat mass (Anant & Venugopal, 2021; Buttichak et al., 2019; Cakmakçi, 2011; Lee et al., 2016; Prakash et al., 2021; Raj & Pramod, 2012; Srinivasulu & Amudhan, 2018; Welling & Nitsure, 2015; Wrotniak et al., 2001; Yaprak, & Küçükkubaş 2020). Such results are expected considering that Pilates exercises, depending on the applied stimuli, cause adaptations of different body tissues.

Along with the increase in skeletal muscle mass, a significant decrease in body fat mass in absolute and relative values was found in the experimental group. Warm-up exercises in the introductory-preparatory phase of training and dynamic exercises on a Pilates ball were mostly performed in a low to moderate intensity zone, suitable for burning body fat. Increased consumption of calories to create energy also occurs during plank exercises (Park & Park, 2019; Park et al., 2021), especially in the later stages of training when there is an accelerated oxidation of fatty acids after carbohydrate reserves have been used up. Therefore, for getting into the lipolysis process, the optimal duration of exercise is important, which, according to evidence from the available literature, should not be shorter than 30 minutes. Thus, Bayrakdar, Demirhan, and Zorba, (2019), who conducted an 8-week high-frequency weekly training on a sample of adolescent swimmers, did not find significant changes in the reduction of body fat because the training sessions lasted only 20 minutes, so the energy for exercise was mainly obtained from carbohydrate stores and to a lesser extent due to the lipolysis process. Similar to the results of Bayrakdar et al. (2019), Yaprak and Küçükkubaş (2020) also did not find a significant decrease in the body fat mass of college students after eight weeks of body core training on an unstable surface. As the reason for the absence of significant changes in body composition, the authors mentioned above cite the training program concept in which isometric endurance exercises such as plank exercises prevailed and an inadequate number of sets and repetitions of each exercise. Even though performing plank exercises increases the consumption of calories to create energy, it is necessary to combine them with activities of low to moderate intensity for more efficient fat burning. Apart from the choice of training stimulants, adequate dosing of all other training stimuli and adequately dosed load progression are also important.

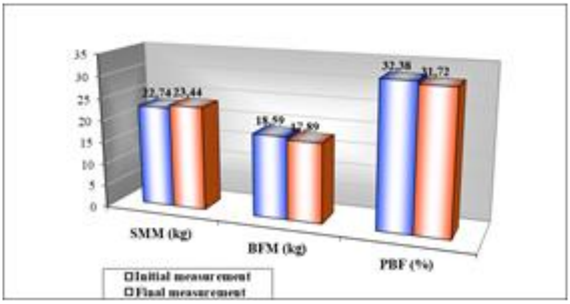
In the study mentioned above, the load progression during the training period was not as gradual or timely as in this study. Still, two training variables (the number of sets and repetitions) simultaneously increased significantly and only once, just in the middle of the training period. Such load dosage is in contrast to FITT training principles because after initial adaptations, stagnation occurs, and overtraining syndrome occurs after a sudden increase in load.

In addition, unlike the results of this study, the study conducted by Vispute et al. (2011) on a sample of non-athlete students did not confirm the effectiveness of ball Pilates on decreasing body fat mass. Namely, Vispute et al. (2011) found only numerical and not statistically significant decreases in body fat mass at the end of the 6-week experimental period. In their study, the participants were older than in this study, so the expected adaptations to training loads were less than in untrained younger participants (Bompa, 2009). Although their study lasted only six weeks, training sessions were performed five times a week, so the total number of training sessions was larger than in this study. Among other things, significant effects were not achieved due to the program concept, which in their study contained only dynamic exercises on a Pilates ball and not stabilizing endurance exercises, the performance of which leads to increased calorie consumption. This was confirmed by the 6-week study conducted by Anant and Venugopal (2021), who, in addition to dynamic exercises on a Pilates ball, also performed stabilizing endurance exercises and found significant effects in reducing body fat. The results of their study are consistent with our study and the results of other studies that combined less intense dynamic exercises with more intense stabilization endurance exercises in their program concept.

Significantly greater effects in reducing body fat than in our study were achieved in the study conducted by Srinivasulu and Amudhan (2018) on a sample of young volleyball players who decreased body fat by 25.98% at the end of the experiment. However, the authors mentioned above conducted the ball Pilates training in combination with plyometric exercises and the usual volleyball training. It is evident that these additional activities, predominantly aerobic, contributed to the established effects to a certain extent.

Generally, differences in the effectiveness of training programs applied in different studies are conditioned by the choice of exercises following the initial fitness and functional capabilities of the respondents, the intensity and duration of exercise, and the adequately dosed load progression throughout the training period. It would be preferable to perform low to moderate-intensity exercises in combination with strength training and obligatory changes in the diet regime. It is important to emphasize that variations in the degree of fat tissue adaptation certainly depend on numerous other factors, such as genetic factors, gender, age, nutrition quality and caloric intake, sleep quality, stress, status of certain hormones, and other factors that were not monitored in this study, but which would enable a more complex understanding of this issue.

In the control group of participants that implemented a standard physical education program, the determined effects of increasing skeletal muscle mass and decreasing body fat mass were small and insignificant. Although the recommended Physical Education teaching contents defined various activities, the control group did not realize them in practice but favored the volleyball and, to a lesser extent, gymnastics contents, only from the floor exercise program. Namely, the recommended Physical Education content defined contents for the development of motor and functional abilities, athletics contents, the program chosen by the students and in accordance with the school facilities, apparatus and floor exercises, the sports game program chosen by the students and following the school possibilities and corrective gymnastics exercises. Contents for developing motor and functional abilities, exercises on apparatus, and corrective gymnastics exercises were not realized, at least not during the 10-week experimental period. At the same time, it is important to emphasize that the school did not have a beam or a vaulting gymnastics horse so the exercises on the beam and vaulting gymnastics horse could not even be realized. For the reasons above, the implemented program of the control group was not in the function of improving body composition, so significant effects were not achieved. The applied exercises, frequency, duration, and intensity in regular Physical Education classes did not represent adequate training stimuli for causing significant changes in body composition (Graph 3).

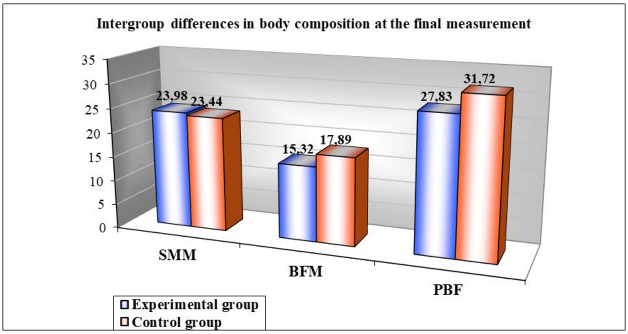


Graph 3 Differences in body composition between the initial and final measurements of the control group

At the final measurement, the groups of participants differed statistically significantly in all body composition parameters. Intergroup differences in body composition favored better results in the experimental group of participants because they had statistically significantly larger average values of skeletal muscle mass and lesser average values of body fat mass.

Medium effects of the applied experimental treatment were determined, which explain 49.7% of the variance in the results of the skeletal muscle mass, 52.6% of the variance in the results of body fat mass in kilograms, and 51.3% of the variance in the results of body fat percentage values.

The results confirmed the superiority of the 10-week body core program on a Pilates ball compared to the standard physical education program in adapting the skeletal muscle mass and body fat mass in the experimental group of participants. The obtained results are in line with the results of the study conducted by Srinivasulu and Amudhan (2018) and Prakash et al. (2021), in which the experimental group that performed ball Pilates achieved significantly greater effects in reducing body fat mass than the control group that performed usual training activities.



Graph 4 Differences between the experimental and control groups in body composition at the final measurement

However, in the study conducted by Lee et al. (2016) on a sample of obese students divided into an experimental group that performed ball Pilates in addition to aerobic training and a control group that performed only aerobic training, the groups of participants at the final measurement did not differ significantly in percentage values of body fat. The training programs of both groups of participants were carried out for eight weeks with a frequency of three training sessions per week, which lasted for 60 minutes and led to a significant reduction in body fat at the final measurement. Still, intergroup differences at the final measurement were not statistically significant. Such results were expected considering that the aerobic training carried out by the control group of participants is based on the exercise programmed to decrease body fat mass.

Conclusion

Exercising on a Pilates ball evokes appropriate physiological and structural adaptations of the various tissues in the human body. Comparing the effectiveness of the standard physical education program and the experimental core body program on a Pilates ball, the study confirmed the superiority of the experimental program in transforming skeletal muscle mass and body fat mass in adolescent girls. The findings of this study are significant primarily from the health aspect and then in the fitness field. Future studies should determine adaptive changes in body composition under the influence of training on a Pilates ball with an appropriate diet and monitor the psychological and motivational factors.

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ADAPTIVNE PROMENE U TELESNOJ KOMPOZICIJI ADOLESCENATA POD UTICAJEM TRENINGA JEZGRA TELA NA PILATES LOPTI

Telesna kompozicija je fitnes komponenta usko povezana sa zdravljem i efikasnošću sportskog performansa pa je njeno proučavanje sastavni deo istraživanja u sportsko medicinskim naukama. Primenom adekvatnih trenažnih programa dolazi do odgovarajućih fizioloških adaptacija i značajnog poboljšanja telesne kompozicije. Ovim istraživanjem je utvrđivana efikasnost desetonedeljnog treninga na pilates lopti na telesnu kompoziciju adolescentkinja, učenica prvog razreda gimnazije. Uzorak od 48 ispitanica, nasumično je bio podeljen na eksperimentalnu (*n*=24) *i kontrolnu grupu* (*n*=24)*. Eksperimentalna grupa je na časovima redovne nastave fizičkog vaspitanja dva puta nedeljno sprovodila program pilatesa na lopti dok je kontrolna grupa sprovodila standardni program fizičkog i zdravstvenog vaspitanja. Eksperimentalni program se sastojao od vežbi balansiranog sedenja, vežbi stabilizacione izdržljivosti i dinamičkih vežbi na pilates lopti za jačanje mišića stabilizatora trupa. Pre početka i na kraju eksperimentalnog perioda kod ispitanica obe grupe su izmerene apsolutne i relativne vrednosti masne mase tela i apsolutne vrednosti skeletno-mišićne mase. Na finalnom u odnosu na inicijalno merenje, kod eksperimentalne grupe su utvrđena statistički značajna poboljšanja i srednji efekti u svim parametrima telesne kompozicije. Kod ispitanica kontrolne grupe, utvrđena poboljšanja su bila numerička, a ne i statistički značajna. Na finalnom merenju utvrđene su statistički značajne razlike i srednji efekti primenjenog eksperimentalnog u skeletno-mišićnoj i masnoj masi tela. Nalazi ove studije su potvrdili efikasnost treninga stabilizatora trupa na pilates lopti u poboljšanju telesne kompozicije adolescentkinja nesportista.*

Ključne reči: *efekti, adolescenti, nemasna masa tela, masna masa tela, stabilnost jezgra tela, pilates lopta*

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Research article

EXPLORING THE INTERPLAY OF PHYSICAL ACTIVITY LEVELS AND QUALITY OF LIFE IN ELDERLY MEN: A MULTIDIMENSIONAL PERSPECTIVE

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Abstract. *As the global population continues to age, understanding and addressing the complex interplay between physical activity (PA) and quality of life (QoL) among old people is becoming increasingly imperative. The aim of this study was to determine whether the level of PA is related to the QoL in elderly men. Using a set of eight variables of PA and four for quality of life assessment, an evaluation of physical activity and quality of life was performed on a sample of 666 senior men (67.37±5.68 years). The level of PA was measured using the IPAQ questionnaire, while the QoL was evaluated by the World Health Organization Questionnaire (WHOQoL-BREF). A canonical correlation analysis was conducted to identify any relationships. Statistical significance was set at p< .01. The results showed that statistically significant relationships were found between moderate PA and the Environmental Health domain of QoL (Sig.= .000). Additionally, relationships were found between overall Walking activity, total PA, and Leisure Physical Activity and Physical and Psychological Health, as well as Social Relationships (Sig.= .003). This study confirmed that different domains of PA are related to the quality of life in elderly men.*

Key words: *old men, exercise, physical health, psychological health, quality of life.*

1. INTRODUCTION

Elderly men represent a distinct demographic group characterized by unique health needs (Paltasingh & Jena, 2021) and behavioral patterns (Schrempft, Jackowska, Hamer, & Steptoe, 2019). As the world's population ages (Vollset, Goren, Yuan, Cao, Smith et al., 2020), it is becoming increasingly important to understand the complex relationships

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between physical activity and quality of life among the elderly. United Nations data indicates a 2% increase in the number of the elderly between 1950 and 2000, with projections estimating that they will make up 22% of the total population by the year 2050 (UNFPA, 2012). Simultaneously, the elderly population reduces overall physical activity (Hakman, Balatska, & Liasota, 2016), impacting their quality of life (QoL). It is currently recommended that older persons engage in 150–300 minutes of moderate-intensity exercise or 75–150 minutes of vigorous-intensity exercise per week. In order gain extra health benefits, it is also advised to perform strengthening exercises two or more days a week at a moderate to high intensity (WHO, 2020).

Physical activity represents a cornerstone in promoting physical health and well-being among elderly men. Regular exercise provides a comprehensive strategy for improving health outcomes in this population (Izquierdo, Merchant, Morley, Anker, Aprahamian et al., 2021), including cardiovascular benefits (Hall, Hyde, Bassett, Carlson, Carnethon et al., 2020), musculoskeletal improvements (Carcelén-Fraile, Lorenzo-Nocino, Afanador-Restrepo, Rodriguez-Lopez, Aibar-Almazan et al., 2023), and metabolic regulation (Pataky, Young, & Nair, 2021). Additionally, engaging in regular physical activity can help manage risk factors such as obesity (Koolhaas, Dhana, Schoufour, Ikram, Kavousi et al., 2017), high cholesterol levels (Chen, Luo, Su, Wang, Fang et al., 2024), and insulin resistance and diabetes (Shabkhiz, Khalafi, Rosenkranz, Karimi, & Moghadami, 2021) thereby mitigating the burden of cardiovascular disease.

Musculoskeletal health is paramount for maintaining mobility, independence, and quality of life in elderly men (Morie, Reid, Miciek, Lajevardi, Choong et al., 2010). Physical activity, particularly resistance training and weight-bearing exercises, has been shown to promote bone density (Maddalozzo & Snow, 2000), muscle strength (Granacher, Lacroix, Muehlbauer, Roettger, & Gollhofer, 2013), and joint flexibility (Stathokostas & Vandervoort, 2016), thereby reducing the risk of falls, fractures, and mobility limitations. Moreover, exercise interventions targeting musculoskeletal health have demonstrated efficacy in improving functional status and enhancing overall physical performance in elderly men (D'Onofrio, Kirschner, Prather, Goldman, & Rozanski, 2023).

The benefits of physical activity extend beyond physical health to encompass mental well-being among elderly men. Regular exercise has been associated with reduced risk of depression (Currier, Lindner, Spittal, Cvetkovski, Pirkis et al., 2020), anxiety (Kazeminia, Salari, Vaisi-Raygani, Jalali, Abdi et al., 2020), and cognitive decline (Law, Lam, Chung & Pang, 2020), as well as improved self-confidence (Franco, Tong, Howard, Sherrington, Ferreira et al., 2015). Furthermore, participating in group-based physical activities can foster social connections, provide a sense of purpose, and enhance overall quality of life in later years (Vagetti, Barbosa Filho, Moreira, Oliveira, Mazzardo et al., 2014). Despite the potential benefits, elderly men may face barriers when engaging in physical activity, including health concerns, lack of social support, and environmental constraints (Spiteri, Broom, Bekhet, De Caro, Laventure et al., 2019). Understanding how different exercise levels interact with physical, psychological, social, and environmental domains of QoL could affect the overall well-being in elderly men.

The World Health Organization (WHO, 1997) defines quality of life (QOL) as "an individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards, and concerns". Therefore, quality of life is a multidimensional concept and encompasses physical, psychological, social, environmental, and personal factors (Sinha, 2019).

Improving overall health can positively impact quality of life, but addressing particular domains is also essential for enhancing overall well-being.

Understanding the nuanced impacts of varying levels of physical activity on the quality of life (QoL) domains in elderly men is paramount for crafting targeted interventions that truly enhance their overall well-being. Low-intensity activities, such as walking or gentle stretching, facilitate mobility (Morie et al., 2010), life satisfaction (An, Chen, Wang, Yang, Huang et al., 2020), and a connection to the natural environment, thereby promoting physical health and a sense of tranquility. Moving to moderate-intensity exercises like cycling or swimming, elderly men not only experience improvements in cardiovascular fitness, and reduce the risk of heart failure (Aune, Schlesinger, Leitzmann, Tonstad, Norat et al., 2021), but also enjoy significant enhancements in psychological well-being, including increased mental health (Marconcin, Werneck, Peralta, Ihle, Gouveia et al., 2022). Meanwhile, high-intensity activities such as resistance training provide robust benefits for physical health (Bai, Soh, Omar Dev, Talib, Xiao et al., 2022) and psychological well-being (An et al., 2020), though they may pose challenges that need to be addressed.

Although evidence demonstrates that, for older adults, PA improves Health-Related Quality of Life (HRQoL) and well-being when compared with minimal or no-treatment controls, there are some interesting mixed results which undermine the claim about the effectiveness of physical activity in improving QoL among the elderly (Marquez et al., 2020). Namely, a study conducted by Baxter et al. (2016) that intended to assess the effectiveness of interventions across the transition to retirement was inconclusive because of insufficient evidence. Another study (Chou, Hwang, & Wu, 2012) revealed no discernible difference in the QoL between Tai Chi, resistance, aquatic, and flexibility exercise groups and control groups among frail elderly individuals. According to Marquez's (2020) systematic review of physical activity and quality of life and well-being, several studies provided too few results to reach conclusions about the relationship between PA and QoL. The inconsistent findings from previous research highlight the importance of further investigation into the relationship between different levels of physical activity and various domains of QoL, especially in particular demographics such as frail older persons, elderly people with different health conditions, elderly men/women, etc. Therefore, it is imperative to delve deeper into these relationships to provide more consistent and conclusive evidence, which can inform interventions and policies aimed at enhancing the well-being of older adults.

Our goal in this study is to clarify the complex relationship that exists between various physical activity levels and elderly men's quality of life in terms of their physical, psychological, social, and environmental domains. Through a multidimensional approach and interdisciplinary collaboration, we endeavor to empower elderly men to lead active, fulfilling, and meaningful lives as they navigate the complexities of aging.

2. METHOD

2.1. The sample of respondents

The old male population, with an average age of 67.37±5.68 years, made up the sample of respondents. There were 666 respondents in the entire sample. The criteria for the selection of respondents was: aged between 60 and 80 years, being physically independent – able to walk 20 feet without assistance or rest, lack of cognitive abilities, impairment and dementia, scored 24 points for educated and 18 points for unqualified respondents in the mini mental state assessment (McDowell, 2006). Also, respondents who recovered from an acute illness were excluded from the study. Participation in the study was voluntary and each respondent could withdraw from the study at any time. All of the respondents were fully informed about the risks and benefits of this study. Table 1 presents the basic characteristics of the respondents.

Table 1 Basic characteristics of the respondents

	Mean	SD
Age [years]	67.37	5.68
Body Hight[cm]	176.17	7.50
Body Weight [kg]	81.42	12.24
BMI [kg/m^2]	26.15	3.33

Legend: Mean – Arithmetic Mean; SD – Standard Deviation

2.2. The sample of measuring instruments

2.2.1. *Physical Activity*

The International Physical Activity Questionnaire, or IPAQ in its long version, was used as a self-assessment tool to estimate the degree of physical activity (Craig et al. 2003). The long IPAQ, with 27 items, gathers information on several domains (workplace, transportation, home, and recreational physical activity) and intensities (vigorous, moderate, and walking), as well as sitting time. For a study requiring a more thorough evaluation, this long format is advised (Craig, Marshall, Sjöström, Bauman, Booth et al., 2003). The metabolic equivalent (MET) concerning minutes per day was used to generate the scores for each reported level of PA. The total weekly MET-minutes (MET-min/wk) were calculated by adding MET-minutes for each PA intensity level (walking/low intensity = 3.3 METs; moderate intensity = 4.0 METs; high intensity = 8.0 METs). The study pattern was used to calculate the MET score (Craig et al., 2003). For all types of physical activity, an average MET score was calculated using the Ainsworth et al. (2011) Compendium. For example, to determine an average MET score for walking, different types of walking were taken into account collectively. The average MET scores for moderate- and vigorous-intensity activities were calculated using the same procedure. Previous research has demonstrated the validity and reliability of the IPAQ questionnaire (Battaglia, Bellafiore, Alesi, Paoli, Bianco et al. 2016; Tran, Do, Pham, Nguyen, Xuong et al. 2020).

2.2.2. *Quality of life*

A short form of the internationally standardized World Health Organization questionnaire, WHOQOL-BREF (Berlim, Pavanello, Cardieraro & Fleck, 2005), was used to measure quality of life. The survey consists of 26 items divided into 4 categories: the Physical Health, Psychological Health, Social relationships, and Environmental Health domain. Individual scores can be found for each category. Every question in the domain was given on a five-point Likert scale, with the following possible answers: (1) minimal, (2) little, (3) moderate, (4) very much, and (5) extreme. Greater values are indicative of a higher standard of living. The WHOQOL-BREF questionnaire validity and reliability were demonstrated in numerous studies (Hanestad et al., 2005; Ohaeri and Awadalla 2009; Ilić et al., 2019; Kalfoss et al., 2021).

2.3. Statistical analysis

The mean and standard deviation (Mean±SD), descriptive statistics of basic elements were computed for each variable. The Pearson correlation coefficient was used to find associations between physical activity and quality of life. A canonical correlational analysis was used to determine the impact of physical activity on the respondents' quality of life. Statistica v10.0 was used as the statistical software to process all of the data. The level of significance was set at .05.

2.4. Study design and procedures

To participate in the study, the respondents had to fill out a questionnaire about their levels of physical activity and quality of life. The researchers provided additional clarification and instructions to each participant about the questionnaires and how to complete them. The respondents filled out the questionnaire by hand. Answers to the questions could be submitted at any time. Participation in the study was completely voluntary, and each respondent had the right to cease their participation at any time while filling out the survey. Notification was given to the respondents that their responses would be kept confidential and that the information would only be utilized for research purposes. Incomplete questionnaires were not included in the further analysis. The questionnaire also contained sociodemographic inquiries. The study was conducted in accordance with the Declaration of Helsinki and standards for research involving human subjects (Christie, 2000; WMA, 2008). The Ethical Board of the Faculty of Sport and Physical Education of the University of Niš approved this research (No. 04-346/2).

3. RESULTS

Basic descriptive characteristics of the predictor and criterion variables are shown in Table 2.

Table 2 Basic descriptive parameters of the predictor and criterion variables.

	Mean	Std. Dev
PA AT WORK	1275.48	2865.83
PA IN TRANSPORT	995.97	1986.80
PA AT HOME	2076.23	2936.96
LEISURE TIME PA	1134.40	2125.06
WALKING	1551.50	2323.86
MODERATE-INTENSITY PA	3000.71	4033.07
HIGH-INTENSITY PA	929.88	1889.49
TOTAL PA	5482.08	6032.22
PHYSICAL HEALTH	23.49	3.48
PSYCHOLOGICAL HEALTH	20.19	2.78
SOCIAL RELATIONSHIPS	9.84	2.04
ENVIRONMENT	27.29	4.81

The cross correlations of predictors and criteria are shown in Table 3. Based on the results shown in Table 3, it can be concluded that cross correlations between the predictors and criteria are low (r=.00-.16).

Table 3 Cross correlations of the predictors and criteria

	Physical Health	Psychological Health	Social Relationships	Environment Health
PA AT WORK	0.04	0.03	0.11	-0.2
PA IN TRANSPORT	0.08	0.07	0.12	0.04
PA AT HOME	0.05	0.08	0.01	0.08
LEISURE PA	0.11	0.16	0.08	0.10
WALKING	0.08	0.11	0.15	0.00
MODERATE-INTENSITY PA	0.12	0.15	0.07	0.12
HIGH-INTENSITY PA	-0.03	-0.04	0.07	-0.01
TOTAL PA	0.10	0.13	0.13	0.08

In order to determine the relationship between the level of physical activity and the quality of life of older men, a canonical correlation analysis was used (Table 4). It was determined that there is a statistically significant relationship between two pairs of canonical factors between the level of physical activity and the quality of life of the elderly men. In both canonical pairs, a statistically significant correlation was found at the level of p=0.00. The canonical correlation of the first pair was 0.23 (R=0.23), and in the second pair was 0.21 (R=0.21). Also, the coefficient of determination for the first pair was 0.05 (R^2=0.05), and for the other was 0.04 (R^2=0.04).

Table 4 An isolated canonical function for elderly men

	R	R^2	Chi-square	df	p
0	0.23	0.05	78.53	32	0.000**
1	0.21	0.04	43.30	21	0.003**
2	0.13	0.02	13.36	12	0.343
3	0.05	0.00	1.54	5	0.909

R – canonical correlation; R2 – coefficient of determination; Chi-square – Bartlett’s Chi-square Test; df – degree of freedom; p – level of significance; ** - p<0.01.

Table 5 shows two canonical pairs presenting both the levels of physical activity and quality of life in older men. In the case of the first canonical pair, within the level of physical activity, the highest value was achieved by total Moderate physical activity (0.51), while the highest value within the quality of life was the Environmental Health domain (0.73). This factor could be named *“Factor of Moderate Physical Activity”*. Also, the highest negative values of the second canonical pair within the level of physical activity were determined for total Walking activity (-0.83), Total PA (-0.71), and Leisure PA (-0.61), while the highest negative values of the second canonical pair within quality of life were determined for Psychological Health (-0.75), Social Relationships (-0.77), and Physical Health (-0.63). This factor could be named “*Factor of Physical Activity at Spare Time*”.

Table 5 Factor structure for the group of elderly men.

PA variables	Root 1	Root 2	QoL variables	Root 1	Root 2
PA AT WORK	-0.33	-0.46	Physical Health	0.44	-0.63
PA IN TRANSPORT	-0.09	-0.58	Psychological Health	0.54	-0.77
PA AT HOME	0.40	-0.17	Social Relationships	-0.26	-0.75
LEISURE PA	0.43	-0.61	Environmental Health	0.73	-0.15
WALKING	-0.22	-0.83			
MODERATE-INTENSITY PA	0.51	-0.55			
HIGH-INTENSITY PA	-0.32	-0.07			
TOTAL PA	0.16	-0.71			

Legend: PA – Physical Activity; Root – factor.

It can be concluded that a statistically significant association was found between Moderate PA and the Environmental Health domain of QoL (p=0.00). Also, a statistically significant association was found between total Walking activity, Leisure PA, and Total PA with Social Relationships, Physical, and Psychological Health (p=0.00).

4. Discussion

The aim of this study was to determine whether physical activity of different intensity was related to the quality of life in elderly men. This study discovered indications for positive relationships between the physical activity of elderly men and several quality of life domains. The study findings showed that there were significant relationships between moderate PA and the Environmental Health domain of QoL. Furthermore, relationships were found between Total PA, overall Walking activity, and leisure PA on the one hand and Physical and Psychological Health, and Social Relationships domains of QoL on the other.

The findings revealed significant relationships between the level of moderate physical activity and the Environmental Health domain among the elderly men. Similar results were obtained in the study conducted by Fox et al. (2007). In their study, moderate physical activity was associated with environmental health, but also with physical and psychological health. According to the WHO (1998), the Environmental Health domain encompasses various aspects crucial to an individuals' overall well-being, including physical safety and security, the home environment, financial resources, accessibility and quality of health and social care, opportunities for acquiring new information and skills, participation in recreation/leisure activities, the physical environment (e.g., pollution, noise, traffic, climate), and transportation. The relationships found in our research suggest that elderly men who engage in moderate physical activity may experience improvements in their environmental segment of quality of life. This could imply that by being moderately physically active, these individuals may perceive their surroundings as safer, more conducive to their needs, and more supportive of their overall well-being. Physical activity of moderate intensity can enhance strength, joint flexibility, balance, and coordination, reducing the risk of falls and injuries (Stathokostas & Vandervoort, 2016; Papalia et al., 2020). Feeling physically stronger and more stable may lead elderly men to perceive their environment as safer and less daunting, thereby improving their overall sense of security. Moderate physical activity can potentially reduce healthcare costs by preventing or managing chronic conditions associated with aging, such as cardiovascular disease or diabetes (Hall et al., 2020; Shabkhiz et al., 2021). With improved health outcomes, elderly men may experience less financial strain related to medical expenses, thereby enhancing their overall financial well-being.

Studies show that total physical activity, walking and leisure physical activity are connected to physical health, as a domain of QoL. The results of previous studies (Koltyn, 2001; Fox et al., 2007) also showed that leisure physical activity is associated with physical health. Leisure physical activity not only includes exercise as a means of improving physical health, but also some other psychological elements that can influence overall health and well-being. Engaging in regular physical activity, regardless of type, is associated with numerous physical health benefits (Hall et al., 2020; Pataky et al., 2021; Izquierdo et al., 2021; Carcelén-Fraile et al., 2023). Leisure activities such as exercise, household chores, or active transportation contribute to improved cardiovascular health, weight management, and overall fitness levels (Koolhaas et al., 2017; Hall et al., 2020; Shabkhiz et al., 2021). These improvements can lead to a higher perceived level of physical health and vitality.

Our results showed that walking is connected to a physical health. Walking is a low-impact form of exercise accessible to most individuals. Regular walking is linked to improvements in health-related physical fitness, and balance (Papalia et al., 2020; Bai et al., 2022), joint function (Stathokostas & Vandervoort, 2016), and overall mobility (Morie et al., 2010). Elderly men who engage in regular walking may experience reduced risk of chronic disease, improved balance, and enhanced stamina, contributing to a better perception of physical health.

The results also show that total PA, walking, and leisure physical activity are connected to Psychological Health, which is congruent with some previous studies (Vuillemin, Boini, Bertrais, Tessier, Oppert et al., 2005; Jurakic, Pedisic & Greblo, 2010). Regular PA is associated with reduced symptoms of anxiety, depression, and stress (Kazeminia et al, 2020; Currier et al., 2020). The release of endorphins during exercise can elevate mood and improve cognitive function (Law et al., 2020), leading to a greater sense of psychological well-being. Elderly men who incorporate regular walks into their routine may experience enhanced emotional resilience and psychological health (Marselle, Warber, & Irvine, 2019). Furthermore, engaging in leisure activities provides opportunities for enjoyment, creativity, and self-expression, which can contribute to positive mental health outcomes.

Our study shows that Total PA, Walking, and Leisure PA are related to Social Relationships. Results from a study by Fox et al. (2007) showed that walking is positively associated with the domain of social relations. That can be explained by the fact that physical activity often involves social interaction, whether through group exercise classes, team sports, or walking with friends. These social connections foster a sense of belonging and support, which are vital for maintaining positive social relationships. Elderly men who engage in regular physical activity may have broader social networks and more opportunities for social engagement (Živković, Milanović, Đošić, Vulpe, Purenović-Ivanović et al., 2024). Leisure PA also provides an opportunity for socializing and connecting with others, and building supportive social networks.

5. CONCLUSIONS

The results provided valuable insights into the correlation between physical activity and various domains of quality of life among elderly men, encompassing Physical Health, Psychological Health, Social Relationships, and Environmental Health. Understanding how different levels of physical activity impact their quality of life empowers elderly men to make informed decisions regarding their health and well-being. By leveraging this understanding, they can adjust their lifestyle to optimize their overall quality of life in their later years.

Moreover, this knowledge carries significant implications for institutions and organizations focused on elderly care. They can utilize these findings to develop tailored policies and programs that promote physical activity among elderly men, thereby supporting their well-being. Implementing initiatives aimed at encouraging physical activity and fostering a supportive environment for elderly men can contribute to a more fulfilling and enjoyable aging experience. The limitation of this study is primarily reflected in the subjective assessment of the respondents. It is assumed that better results would be obtained in the domain of physical activity if objective instruments were used for its assessment. Also, this study is transversal by design. It could be suggested that the study would be improved if it included an organized approach for monitoring physical activity and its relation to elderly men's quality of life.

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ISTRAŽIVANJE ODNOSA IZMEĐU NIVOA FIZIČKE AKTIVNOSTI I KVALITETA ŽIVOTA KOD STARIJIH MUŠKARACA: MULTIDIMENZIONALNI PRISTUP

Kako globalna populacija nastavlja da stari, razumevanje i rešavanje složene međuzavisnosti između fizičke aktivnosti (FA) i kvaliteta života kod starijih osoba postaje sve važnije. Cilj ove studije bio je da utvrdi da li je nivo FA povezan sa kvalitetom života kod starijih muškaraca. Korišćenjem seta od osam varijabli FA i četiri za procenu kvaliteta života, izvršena je evaluacija fizičke aktivnosti i kvaliteta života na uzorku od 666 starijih muškaraca (67,37±5,68 godina). Nivo FA je meren pomoću IPAQ upitnika, dok je kvalitet života procenjen putem upitnika Svetske zdravstvene organizacije (WHOQoL-BREF). Korišćena je kanonička korelaciona analiza za identifikaciju odnosa. Statistička značajnost je postavljena na p< .01. Rezultati studije su pokazali da su utvrđene značajne veze između umerene FA sa domenom kvaliteta života koji se odnosi na životnu sredinu (Sig.= .000). Pored toga, pronađene su veze između ukupne aktivnosti hodanja, ukupne FA i fizičke aktivnosti u slobodnom vremenu sa fizičkim i psihološkim zdravljem, kao i sa socijalnim odnosima (Sig.= .003). Ova studija je potvrdila da su različiti domeni FA povezani sa kvalitetom života kod starijih muškaraca.

Ključne reči: *stariji muškarci, vežbanje, fizičko zdravlje, psihološko zdravlje, kvalitet života.*

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