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Acknowledgements

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Research article

SMALL-SIDED GAMES VERSUS INTERVAL TRAINING IN ADOLESCENT SOCCER PLAYERS: EFFECTS ON BODY COMPOSITION

*UDC 796.015.132:611
796.332-053.6*

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Abstract. *The aim of this research was to determine the effects of small-sided games (SSGs) and high-intensity interval training (HIIT) on body composition in adolescent soccer players. A total of 60 young male soccer players (Age: 15.6±0.6 years) were recruited. We registered the following body composition variables: body fat, percentage of fat mass (BF%), muscle mass, body mass, total body water (TBW), and BMI. Players were randomly assigned to the SSG or HIIT group during the last eight weeks of the season. The HIIT group showed significantly improved body fat and body fat % (p≤0.05), whereas no change was observed for body mass, BMI, body water and muscle mass in both groups. In conclusion, HIIT training improved or maintained body composition status in adolescent soccer players. On the contrary, SSG training seems to increase body fat and consequently affect players' performance at the end of the season.*

Key words: *Soccer, Conditioning, In-Season, Body Composition, Effects*

INTRODUCTION

Nowadays, body composition assessment is considered a usual and elementary component of elite level soccer (Milsom et al., 2015). It was shown (Gravina et al., 2008) that better players are leaner than lower-level players, even in the younger age categories. Moreover, it was stated recently that elite senior players show grater increases in lean mass compared to junior player (Bilsborough et al., 2010). Similarly, Milsom et al. (2015) found

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that professional soccer players from the English Premier League differ in whole body and regional aspects of body composition according to different age and training history.

During one soccer match, elite adolescent soccer players often cover distances greater than six kilometers during which an intermittent activity has the most important roll for performance and success (Bucheit, Mendez-Villanueva, Simspon & Bourdon, 2010). High-intensity interval training (HIIT) and Small-sided games (SSG) are a very popular and effective form of exercise with small time requirement.

One paper found similar results for HIIT and traditional aerobic conditioning for improving (VO2max) in female collegiate soccer players (Rowan, Kueffiner & Stavrianeas, 2012). More recently, Howard and Stavrianeas (2017) found in high school soccer players that both the endurance training group and the high-intensity interval training group showed significant improvements in aerobic fitness. In one study, conducted on 14-year-old soccer players peak VO2 increased significantly following 5 weeks of HIIT compared to high-volume training (Sperlich et al., 2011). Concerning body composition in soccer, Carling and Orhant (2010) found significant changes in body fat after a six-month training program.

In contrast, small-sided games (SSGs) have been used for years in soccer. However, SSGs have only recently been the focus of scientific research because of their effects on physical capacity, while the technical and tactical parameters remain on the same level (Dellal, Varliette, Owen, Chirico & Pialoux, 2012). Moreover, coaches and players generally prefer the use of SSGs (Dellal, Lago-Penas, Wong & Chamari, 2011).

However, SSGs might not be an ideal solution for all playing standards and levels because Dellal et al. (2012) revealed that the physiological responses to SSG were skill and level dependent.

Although the effects of SSGs versus HIIT have been already compared in elite soccer players (Impellizzeri et al., 2006), to the authors' knowledge no studies have yet attempted to compare the effects of SSGs and HIIT on body composition in adolescent soccer players. Therefore, the aim of this research was to determine the effects of SSG and HIIT on body composition in adolescent soccer players.

METHODS

Participants

A total of 60 young male soccer players (15.6±0.6 years old) were recruited (Table 1). Written informed consent was obtained from the players and their parents. All participants were from a professional soccer club and completed on average 10 hours of combined soccer training and competitive play per week. The experimental protocol received approval from the institutional ethics committee from the Faculty of Sport and Physical Education, University of Novi Sad.

Table 1 Basic descriptive statistics of adolescent soccer players

Descriptive variables	Mean±SD
Age	15.6 ± 0.6
Height	177.64 ± 6.5
VO_{2max}	52.1 ± 2.04
Experience (years)	6.4 ± 2.5
Training (min·week-1)	401 ± 122

Testing procedures

Body height was measured under standard conditions. The InBody 230 (Biospace Co. Inc., Seoul, South Korea) Bioelectrical Impedance Analyzer (BIA) was used. This foot-to-foot, hand-to-hand and hand-to-foot contact device uses two stainless-steel foot pad electrodes mounted on a platform scale and two stainless steel handles to allow for a Tetrapolar eight-point tactile electrode system. The platform scale uses a single load cell to measure body mass (with a measure of stature) and calculate the body mass index (BMI). Body fat percentage was determined using a summation of a segmental lean analysis to determine total lean body mass, fat mass, and ultimately the proportion of fat to total weight mass fraction. An estimate of muscular percentage was derived by Body weight (0.1 kg) – measured using InBody 230, evaluating water content in the segmental regions using proprietor equations. The participants entered the testing area and removed their shoes and socks and wore only light clothing. Once positioned on the In-Body 230, their age, sex, and stature were entered. The InBody 230 displays a visual cue (photo) how and when to hold the handles during the impedance measure. We registered the following body composition variables: body fat (BF), percentage of fat mass (BF%), muscle mass, body fat mass, total body water (TBW), and BMI.

Training program

The players were randomly assigned to the SSG (28 players) or HIIT group (32 players) during the last eight weeks of the season. In addition to the SSG and HIIT programs, all players continued to participate in their usual training (technical and tactical) sessions and official games. It was ensured that all the players received the same training routines, except for the HIIT and SSG parts.

HIIT training

High-intensity interval training was performed over 40-m shuttles, with 15s-15s, intermittent runs (Table 2). The individual intensity of the runs was selected according to the players' V30-15IFT as previously shown (Bucheit, 2008).

Table 2 HIIT training program

Week	Protocol	VIFT-Based Intensity
1	3 sets (5 reps of 15"-15" HIIT)	90% VIFT
2	3 sets (5 reps of 15"-15" HIIT)	90% VIFT
3	3 sets (8 reps of 15"-15" HIIT)	90% VIFT
4	3 sets (8 reps of 15"-15" HIIT)	90% VIFT
5	4 sets (6 reps of 15"-15" HIIT)	95% VIFT
6	4 sets (8 reps of 15"-15" HIIT)	95% VIFT
7	4 sets (6 reps of 15"-15" HIIT)	95% VIFT
8	4 sets (6 reps of 15"-15" HIIT)	95% VIFT

VIFT - speed of the final phase completed in full

Small-sided games

The content of the SSG programme was inspired and modified from several protocols. We used a team size of 3 or 4 players on each team because it elicits the best responses, both physiologically and in terms of skill development (Jeffreys, 2004). Mean HR during the SSG training sessions was 154±18 bpm (85-89% of HRpeak). The exercise program was performed over eight weeks. The sessions were performed in the 4x4 and 3x3 method on a 20x15m, 25x18 field. The protocol included several rule changes in order to increase the intensity of play. No goalkeepers were allowed. Maximum of two touches were allowed during the first ten minutes. Moreover, each time the ball went out of play, the coach immediately fed in another ball, resulting in a constant flow of the play and thus avoiding any notable decrease on the physical demands of the player. These exercises were done twice a week.

Statistical analysis

Data were tested for normality with a Shapiro-Wilk normality test. To test within-group changes, differences were analysed using a paired *t* test. An analysis of covariance (ANCOVA) with baseline data as a covariate and groups as a between-subject comparator was used to evaluate the main and intervention effects. If the data were not normally distributed, a Kruskall-Wallis test by ranks with Dunn's *post hoc* test was used. Statistical analyses were processed using SPSS Statistics (SPSS Inc., Chicago, IL, USA, version. 16.0). The data are expressed as mean ±SD and the alpha value of significance was $p \leq 0.05$.

RESULTS

The HIIT group showed significantly changed body composition after eight weeks (Table 3). The HIIT group showed significantly improved BF and BF%, compared to the SSG group ($p \leq 0.05$), whereas no significant changes were observed for body mass, BMI, TBW and muscle mass in both groups.

Table 3 Mean ± SD results of different body composition parameters before and after 8 weeks of SSG and HIIT training

	SSG group N=28		HIIT group N=32	
	Baseline	Final	Baseline	Final
Body Height	176.29 ± 6.1	176.49 ± 6.2	180.57 ± 6.6	180.77 ± 6.5
Body mass	63.41 ± 9.71	64.45 ± 8.61	71.89 ± 9.12	72.72 ± 8.73
Body water	41.49 ± 4.98	41.73 ± 5.01	46.75 ± 6.04	47.41 ± 6.00
Body fat	6.75 ± 4.85	7.49 ± 3.55	8.02 ± 1.82	7.44 ± 1.22*
Body fat %	10.25 ± 4.97	11.44 ± 3.99	11.20 ± 2.02	10.96 ± 2.92*
BMI	20.35 ± 2.52	20.72 ± 2.11	21.98 ± 1.89	22.23 ± 1.79
Muscle mass	31.93 ± 4.11	32.08 ± 4.16	36.42 ± 5.02	37.01 ± 4.99

* Significantly different from the SSG group, $p<0.05$

DISCUSSION

The main aim of this study was to examine the effects of SSGs and HIIT on body composition in adolescent soccer players. The main finding of our study was that HIIT training was more effective than SSGs in maintaining body composition status in adolescent soccer players during the last weeks of the season. Moreover, the results of this study revealed that eight weeks of soccer training including HIIT significantly improved body composition in adolescent soccer players.

As far as the difference between groups is concerned, our results suggest that both groups demonstrated changes in body mass, but without statistical significance. However, BF and BF% changed significantly in the HIIT group ($p<0.05$) compared to the SSG group.

The game of soccer has an intermittent nature, and consequently, HIIT was used to simulate the demands of a match-play (Iaia, Eemanno & Bangsbo, 2009; Orendurff et al., 2010). It was stated that HIIT training improves not only maximal aerobic performance and VO_{2max} (Wong, Chaouachi, Chamari, Dellal & Wisloff, 2010) but also solicits anaerobic metabolism (Dellal et al., 2010). Dellal et al. (2011) found similar results for both the SSG and HIIT training for improving aerobic performance.

Body composition is not only considered a prerequisite for health, but also firmly fits in the structure of sport performance and together with other factors determines the quality of human motion and the final level of performance (Williams, Drust, Williams, & Ford, 2013). Regarding the findings of body composition values, the present results indicated that after an eight-week training program, BF and BF% levels of the HIIT group decreased compared to the increase obtained by the SSG group. Based on these results, the increase in body mass of both groups, from baseline to final measurement, was logical and could be explained by a gain in lean tissue. Increases in lean tissue result from gains in muscle tissue, suggesting that the players' strength also improved. Moreover, the young soccer players' reports of high percent body fat could be due to low absolute levels of lean mass and not high levels of fat mass, which is not the case with senior player (Milsom et al., 2015).

BF is a standard measurement in soccer because better players tend to be leaner than lower-level players, even in the younger age groups (Gravina, Gil, Ruiz, Zubero, Gil & Irazusta, 2008; Janssens, Van Renterghem, & Vrijens, 2001). Contrary to our results, Campo et al. (2009) revealed no significant effects on BF following plyometric training in female soccer players, and that may be because of the absence of organized training during the transition period appears to increase BF in soccer players (Sotiropoulos, Travos, Gissis, Souglis & Grezios, 2009). The aforementioned authors also found that soccer players that were involved in a training program during the transition period achieved significantly lower BF% compared to the control group.

As far as the BF% results are concerned, the value of ~11% was similar with those of some other studies (Casajus, 2001; Rakhila & Luhtanen, 1991; Rhodes et al., 1986; Rico-Sanz, 1998; Rico-Sanz et al., 1998), but lower compared to the results of Matkovic et al. (2003) recorded among Croatian elite players (14.9%). These differences in results could be due to different methods of body fat assessment, but also differences in training programs (Silvestre, West, Maresh & Kreamer, 2006). There is a decreasing trend in BF and body mass across the season in soccer (Mercer, Gleeson & Mitchell, 1997; Ostojic, 2003; Reilly, Bangsbo & Franks, 2000), which is mainly due to body composition status during the off-season.

CONCLUSION

In the off-season, players became deconditioned, with low fitness levels. During pre-season they are often involved in a rigorous training programme (usually twice a day), which results in large decreases in BF. Moreover, the possible reason for discrepancy in the results could be the differences in the length and content of pre-season training. During the last weeks of the season, HIIT training in addition to the technical and tactical training improved or maintained body composition status in adolescent soccer players. On the contrary, compared to HIIT training, SSG training seems to increase BF and BF%, consequently affecting players' performance at the end of the season.

Acknowledgement: *We thank Football Club* Spartak Zdrepceva krv *from Subotica (Serbia) for their contribution and participation in this study, the coordinator for younger categories Ivica Franciskovic, and coaches Bogoljub Dzinic and Saso Djurasovic.*

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IGRE NA MALOM PROSTORU (SSG) NASUPROT INTERVALNOM TRENINGU KOD MLADIH FUDBALERA: EFEKTI NA TELESNU KOMPOZICIJU

Cilj ove studije bio je utvrditi efekte igara na malom prostoru (SSG) i visoko intenzivnog intervalnog treninga (HIIT) na telesnu kompoziciju kod mladih fudbalera. Ukupan broj učesnika u ovoj studiji bio je 60 (Uzrast: 15.6±0.6 godina). Za procenu telesne kompozicije korišćene su sledeće varijable: telesne masti, procenat telesnih masti (BF%), mišićna masa, telesna masa, ukupna količina vode (TBW) i BMI. Igrači su bili nasumično raspoređeni u SSG ili HIIT grupu tokom poslednjih osam nedelja u sezoni. HIIT grupa pokazala je značajno poboljšanje telesnih masti i procenta telesnih masti ($p\leq 0.05$),dok promene nisu uočene u telesnoj masi, BMI, telesnoj vodi i mišićnoj masi u obe grupe. Zaključili smo da je HIIT trening poboljšao ili zadržao postojeći status telesne kompozicije mladih fudbalera. S druge strane, SSG trening je povećao telesne masti i time uticao na performanse igrača na kraju sezone.

Ključne reči: *fudbal, kondicija, sezona, telesna kompozicija, efekti*

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Research article

DEVELOPMENT OF A SCALE FOR ASSESSING THE QUALITY OF MASS RECREATIONAL EVENTS

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Abstract. *Regular physical activity is one of the most important factors for maintaining health and quality of life. Mass recreational sports events is a good way to promote physical activity. In this research, the Sports Olympics of Vojvodian Workers (SOVW) was evaluated as an example. The main aim of the study is to analyze a recreational sports event as a mass activity significant for public health. The secondary aim is the development of a valid questionnaire which is applicable in practice. On a sample of 205 participants of the 12th SOVW, of different age and gender, an instrument was applied that showed a good metric. The factor analysis gave a stable one-factor model with a unique scale for assessing the quality of mass recreational sports events. It is a simple and understandable questionnaire, easily applicable in practice. The results of this study showed that the ratings of respondents of different age and gender did not differ significantly. The SOVW was evaluated as an event of medium quality (total score amounts to 66.19% of the maximum).*

Key words: *Physical Activity, Recreation of Employees, Quality Measurement, Mass Event*

1. INTRODUCTION

Sedentary lifestyle is characteristic of modern humans and the frequent cause of many chronic non-communicable diseases (Atorkey, 2019; Kandola, Stubbs and Koyanagi, 2020; Uddin et al., 2020; Wagner and Brath, 2012; WHO, 2018). Regular physical activity is one of the most important factors for maintaining health and quality of life. Mass recreational sports events are often used to promote exercise and health, particularly among adult employees. Quality evaluation plays a significant role in the management of any recreational sports event. The universal definition of the quality of mass sporting

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events and the standard way of their assessment do not yet exist. In research practice, the most used standards and instruments belong to the service quality area and are tailored to the specificities of each individual event (Nešić, Ahmetović, Srdić and Badrić, 2017). Service quality is based on the opinion of the users formed during the consumption of the offered content, but it can also be analysed as the quality of the relationships established between the users and the service providers (Segoro, 2013).

Services in sports and recreation are processes whose results have an intangible form (Vargo and Morgan, 2005). The successful functioning of sport-recreative providers depends on the level to which they meet the needs of their users (Kaplan, 2001) and whether they have the organizational capacity to deliver quality services (Nešić, Dačić and Srdić, 2014). The social environment and user characteristics have a significant impact on the perception of service quality (Grönroos, 2002). In addition to objective indicators of service quality, customer experience is also very significant, and it depends on culture, psycho-social characteristics, beliefs, expectations, the adopted value system, habits and desires (Evans and Lindsey, 2010). The biggest difficulties when evaluating the quality of sport-recreational events are related to the dilemma of what is more important to measure: tangible quality indicators or customer experiences (Cairns, Harris, Hutchison & Tricker, 2004). Another methodological problem is related to the objectivity of quality assessment. Modern researchers think that the main focus of service quality measuring should be directed towards customer experience (Cairns et al., 2004; Campbell, 2002).

Several different instruments have been created in research practice to assess the quality of services. The SERVQUAL model was used most (Parasuraman, Zeithaml & Berry, 1988; Parasuraman et al., 1991), which measures the gaps between customer expectations and their perception of quality after using the service, followed by its variation SERVPERF (Cronin and Taylor, 1992). SERVQUAL recognizes five dimensions of quality: reliability (the ability to perform the promised service dependably and accurately), assurance (the knowledge and courtesy of the employees and their ability to convey trust and confidence), tangibles (the appearance of the physical facilities, equipment, personnel and communication materials), empathy (the provision of caring, individualized attention to customers), and responsiveness (the willingness to help customers and to provide prompt service). Many researchers have adapted SERVQUAL for the specific needs of their studies (Backman and Velfkamp, 1995; Crompton et al, 1991; Hung-Chih Yu, Morais and Chick, 2005).

Crompton (1991) did not obtain interpretable results by applying SERVQUAL to evaluate the quality of sport and recreation services and proposed a new questionnaire known as REQUAL. His scale contains four dimensions of quality (security, reliability, accountability and tangibility). Kim and Kim (1995) developed the QUESC model (Quality Excellence of Sport Centres) on a sample of sports centres in Korea. This model measures as many as 12 dimensions of quality: ambience, employee behaviour, employee reliability, sociability, information availability, programs offered, staff reputation, prices, privileges, serenity, incentives and benefits. McDonald et al. (1995) presented the TEAMQUAL model. They tested 39 elements, based on five original SERVQUAL dimensions. Howat et al. (1999) developed the CERM-CSQ model (Centre for Environmental and Recreation Management – Customer Service Quality) which measures three dimensions of quality: the main services, personal and peripheral services. The authors often used this model to measure the service quality of fitness centres in Australia and New Zealand (Murray and Howat, 2002). Ko and Pastore (2004, 2007) developed a detailed scale for service quality measuring in recreational sports (SSQRS). Four dimensions are isolated: program quality, interaction quality, outcome quality, and physical environment quality. Based on this instrument, Ko et. al. (2011) developed the MEQSS (Model of Event Quality for Spectator Sport). Testing whether visitor satisfaction with small outdoor sporting events acts as a mediator of the relationship between service quality and immediate behaviour, Tzetzis, Alexandris and Kapsampeli (2014) implemented a model with the following three dimensions of quality: approach, venue, and content. At the karate club example, Perić et al. (2017) offered an instrument for assessing the service quality of specific sports organization (SQKC questionnaire). The instrument has a unique scale for service quality measurement and has demonstrated good validity and reliability.

The aim of this study was to test the metric characteristics of an instrument for assessing the quality of a mass recreational sports events (MRSEQ). The research was conducted as a case study named the Sports Olympics of Vojvodian Workers (SOVW). The specific instrument was constructed by using elements of the previously cited instruments (selected questions and statements), and corrected during a few pilot studies. The final version of the instrument was applied at the last Olympics held in 2019.

2. METHOD

2.1. Sample

The study was conducted on 205 respondents (119 male) of the 12th Vojvodian Workers' Sports Olympics (SOVW). The respondents' ages ranged from 18 to 65 years, and the following distribution was obtained: 28 (13.7%) respondents under 24 (Youth), 91 (44.4%) participants between 25 and 39 (Young Adults), 73 (35.6%) respondents between 40 and 60 (Middle Adults), and 13 (6.3%) respondents over 60 (Older Adults). The sample is very representative because there were a total of 463 participants in the 12th SOVW.

A survey was conducted among the participants during 3 days of competition in Novi Bečej. The respondents were randomly selected, and the only criterion was to answer the survey questions voluntarily and honestly. Everyone was informed of the survey aim and resolved the questionnaire anonymously.

2.2. Variables and materials

For the purpose of this research, a questionnaire was designed to evaluate the quality of mass recreational sports events (MRSEQ). The questionnaire consists of 19 items (variables) according to which the respondents express their position by selecting the appropriate position on a 5-point Likert-type scale. A scalar value of 1 means complete dissatisfaction, and a value of 5 means complete satisfaction with a particular aspect of quality. The basis for defining the item-statements were instruments used in previous similar research (Shonk, Carr and De Michele, 2010; Currie and Ipson, 2002; Jae Ko and Pastore, 2004; Lee et al., 2011; Packianathan and Kyungro, 2000; Perić et al., 2016 i 2017; Tzetzis et al., 2014). Items that showed good metrics in previous research were included in the initial instrument. Nineteen items (Table 1) were defined, which hypothetically related to three aspects of quality: 1) event management (Items No: 1, 4 and 8), 2) the role of the local community (Items No: 2, 3, 5, 6, 7, 14, 15, 18 and 19) and 3) involvement of the company (employers) where the participants are employed (Items No: 9, 10, 11, 12, 13, 16 and 17). Cronbach's Alpha was significantly higher than the recommended theoretical value of 0.7 (DeVellis, 2003) and showed that the initial instrument had good internal reliability.

Table 1 Results of Scale reliability analysis for the initial questionnaire of 19 items

No	Items (Variables)	Cronbach's Alpha if Item Deleted	Mean	SD
V1	Conditions for SRA in the company where you work	0.918	2.87	1.370
V2	Conditions for SRA in the place of residence	0.911	3.99	0.937
V3	Conditions for SRA in the municipality	0.911	3.97	0.920
V4	Real-world opportunities for SRA in a company	0.915	3.27	1.311
V5	The prevalence and organization of SRA in the country	0.907	3.64	1.161
V6	Local politicians' support for RSE	0.908	3.07	1.312
V7	Financing RSE at the municipal level	0.906	3.07	1.272
V8	Financing SRA by employers	0.915	3.16	1.294
V9	Regularity and respect for RSE in the country	0.907	3.80	0.943
V10	The current sustainability of the RSE concept	0.908	3.97	0.936
V11	Quality of the RSE organization at the national level	0.909	3.93	0.916
V12	RSE organization at the municipal level	0.907	3.94	0.960
V13	General organization RSE where you participate	0.908	4.02	0.931
V14	The host city relation to the RSE where you participate	0.909	4.17	0.947
V15	Quality of facilities and equipment for competitions	0.912	3.98	0.918
V16	The attractiveness of the RSE competition program	0.909	4.01	0.863
V17	Accompanying entertainment and educational content	0.907	4.07	1.029
V18	Severity of RSE promotion and general media support	0.906	3.54	1.274
V19	Media coverage of RSE where you participate	0.907	3.60	1.247
	Cronbach's Alpha	0.920	3.688	0.407

2.3. Statistical analysis

The gathered data were processed using descriptive and comparative statistical procedures. Descriptives (Mean and Std. Deviation) were calculated from scalar values used by the participants to express their opinion. Scale reliability was tested by using Cronbach's Alpha. The questionnaire validity was assessed by Factor analysis (model: Principal Components Analysis, PCA), using the Direct Oblimin method of rotation and Kaiser Normalization. The effect of gender and age on the differences between the Mean in different subgroups was tested using the Two-Way Analysis of Variance, ANOVA (Tabachnick and Fidell, 2013). All the conclusions were realized on the 0.05 level of significance ($p<0.05$).

The portable IBM SPSS v.21 application (License Stats Prem: 761b17dcfd1bf20da576 by Hearne software) was used for complete statistical analysis.

3. Results

3.1. Factorial validity of the instrument

Factor analysis of the principal components (PCA) was conducted on the data collected using the initial 19-item questionnaire. Assessment of the suitability of the data for factorization preceded the explanation of the components. Many coefficient values of 0.3 or more were recorded by a review of the correlation matrix. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) was 0.879, which is higher than the recommended minimum theoretical value of 0.6 (Kaiser, 1970; 1974). Bartlett's test of sphericity (Bartlett,

1954) also indicated the statistical significance of the obtained factor model (Chi-Square =2391.795; p=0.000). These statistics proved the good factorability of the correlation matrix.

A principal component analysis, which was obtained after Oblimin rotation, revealed as many as five components with Eiegenvalues over 1. The obtained Scree plot (Fig. 1) shows that the scree point was already behind the first component. Based on Kattel's (1966) criterion, it was decided only one component that was above the scree point would be retained. This decision was supported by the results of a parallel analysis (Horn, 1965) that used a matrix with 19 variables, 205 subjects and 100 replications (Watkins, 2000), because only the first characteristic value was less than the corresponding empirical Eiegenvalue.

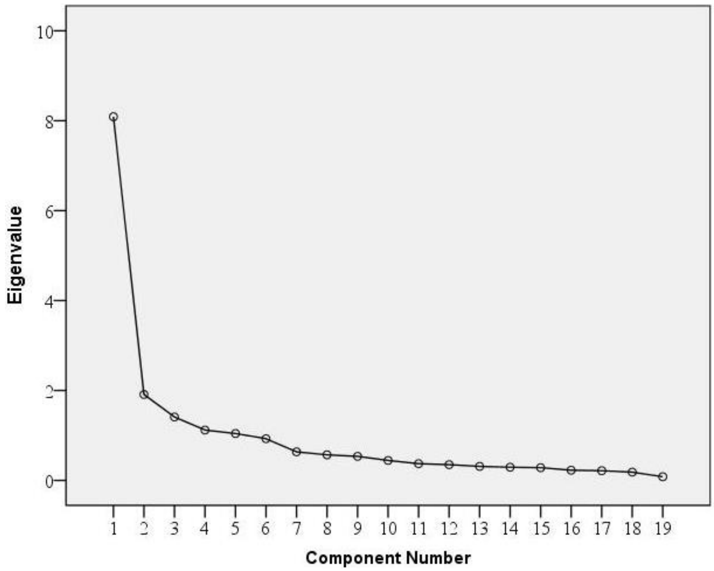

Fig. 1 Scree plot for results obtained from the initial questionnaire

The same PCA procedure was repeated for the one-component solution. Among the received utilities, three values (for variables 1, 4, and 8) were less than 0.3, which is why all three were eliminated from the system, and then PCA was repeated with the retained 16 variables. The newly obtained solution was very stable and confirmed the fulfillment of basic statistical assumptions for the application of a factor analysis (KMO=0.889; Chi-Square =2146.063; p=0.000). This one-component solution explained a satisfactory 48.664% of the total variance. All 16 communalities were over 0.3, which fulfilled the recommended statistical criterion (Thurston, 1947). Each of the 16 retained variables gave significant factor loading to the principal component (Table 2). This one-factor solution proves the high validity of the 16-item MRSEQ instrument and enables it to be used as a single scale to measure the quality of mass recreational sports events.

Table 2 Factor analysis results conducted on 16 retained variables (hierarchical view)

No	Variables	Factor Loadings	Communalities
13	General organization RSE where you participate	0.766	0.587
17	Accompanying entertainment and educational content	0.760	0.577
12	RSE organization at the municipal level	0.752	0.565
16	The attractiveness of the RSE competition program	0.750	0.562
10	The current sustainability of the RSE concept	0.745	0.554
18	Severity of RSE promotion and general media support	0.722	0.521
19	Media coverage of RSE where you participate	0.715	0.512
7	Financing of RSE at the municipal level	0.711	0.505
9	Regularity and respect for RSE in the country	0.710	0.504
11	Quality of RSE organization at the national level	0.695	0.483
5	The prevalence and organization of SRA in the country	0.694	0.481
14	The host city relation to the RSE where you participate	0.687	0.472
6	Local politicians' support for RSE	0.680	0.462
15	Quality of facilities and equipment for competitions	0.595	0.354
2	Conditions for SRA in your place of residence	0.574	0.329
3	Conditions for SRA in the municipality	0.563	0.317

SRA = Sports and recreational activities; RSE = Recreational sports events

3.2. Normative scale data

Confirmation that it is possible to use MRSEQ as a single scale allows the final result of quality measurement to be expressed as a total score, or to calculate the sum of 16 estimates (scalar values). The total score is in the range of 16 to 80 because the maximum scalar value is 5 and the minimum is 1 for each item. A larger score indicates that a mass recreational sports event is more valuable (higher quality). The score obtained in this way enables the comparison of similar events in the world, but also the quality of the same event over time.

Data from this study were collected during the 12th Sports Olympics of Vojvodian Workers (SOVW) and were used to evaluate it. For each subgroup formed by age and gender, as well as for the complete sample, average scores (Mean) were calculated (Table 3). The results of the ANOVA (Table 4) revealed that age and gender individually, as well as interactively, did not

Table 3 Descriptive parameters for the MRSEQ scores obtained in different subgroups

Age group	Gender	N	Mean	SD
Youth	Male	14	50.71	11.364
	Female	14	53.57	8.715
	Total	28	52.14	10.043
Young Adults	Male	59	49.85	10.975
	Female	32	54.13	10.051
	Total	91	51.35	10.800
Middle Adults	Male	38	53.29	8.902
	Female	35	56.11	9.193
	Total	73	54.64	9.091
Older Adults	Male	8	59.75	11.756
	Female	5	51.00	1.000
	Total	13	56.38	10.029
Complete sample	Male	119	51.71	10.654
	Female	86	54.66	9.180
	Total	205	52.95	10.144

significantly influence the differences between the Mean. This allowed the MRSEQ score to be interpreted for the complete sample. The average score in this case is 52.95 (or 66.19% of the maximum), which marks the 12th SOVW as a medium-quality mass recreational event. Th coefficient of variation (SD / Mean = 0.19) was very low, proving the homogeneity of all the respondents' scores and increasing the conclusion probability.

Table 4 Results of ANOVA obtained for the data from Table 3

Impact	F	p	Partial Eta Squared
Age & Gender	1.529	0.208	0.023
Age	1.262	0.289	0.019
Gender	0.026	0.873	0.000

4. Discussion

4.1. The scale metrics and structure

By applying the appropriate statistical procedures (Scale Reliability and Factor Analysis), it was determined that the final 16-item questionnaire had high validity, confirming that proper items were taken from previous research and that a new scale could be used in practice. The items related to the organization of events (variables 13 and 12) and to the contents offered to the respondents (variables 17 and 16) gave the greatest loadings to the general factor. It is important to note that the accompanying entertainment and educational contents have more factor loadings than the competition program. This shows that psycho-social motives are dominant among participants in mass recreational sports events (MRSE). This information justifies the fact that MRSE organizers pay considerable attention to the accompanying contents that emphasize the socialization needs of the modern human. The host city of the event (the 12th SOVW) organized concerts of several popular national bands, and engaged a scientific-educational institution (Faculty of Sport and Tourism from Novi Sad) to conduct anthropometric and functional testing of the participants and organize a knowledge quiz. The quality of the accompanying entertainment and educational content (variable 17) had the second highest scalar average among the ratings of particular aspects of the event (Table 1).

Observation of the dominant role of the socialization aspects of MRSE is supported by information on the items ranks related to the material conditions (facilities and equipment) in which the SOVW was organized. Variables 2, 3 and 15 (Table 2), namely, had the least factor loadings . This confirms the findings of previous studies (Caro and Garcia, 2007; Derom and Taks, 2011; Lynch and Dibben, 2015; Okayasu, 2016; Perić et al., 2016 and 2017; Rauter, 2014) in which intangible (psycho-social) elements influenced participants' satisfaction more than material conditions (facilities and equipment).

It is important to look at the items that were eliminated from the initial questionnaire (variables 1, 4 and 8 at Table 1). All three items indicate the employers' attitudes toward the employees' recreational and sports activities (material requirements and support for participation in MRSE). These items had very low communalities and a negligible share in explaining the total variability. These were also the elements that were the least rated by the respondents (Table 1). The low predictive value of these three variables can be explained by the fact that their estimates were the least homogeneous, that is, they had the highest standard deviations (SD) with the least Mean. The results of this study show that employers in Serbia do not pay sufficient attention to regular physical activity and that they are saving on healthcare in order to maximize profits. Employees in Serbia today have to take care of their recreational exercise themselves. Education is important for the selection of healthy activities and their proper implementation, so these contents could be the trump card of the organizers to improve the quality of the next SOVW.

In addition to the items related to the role of employers (companies in which the respondents are employed), specific items that evaluate the role of two important public life entities - the municipality (variables 12 and 7) and the state (variables 9, 11 and 5) - are represented in the hierarchical structure of the MRSE general factor. Municipality-related items have higher factor loadings and are in higher positions than all state-related items. This shows that the improvement of the quality of MRSE (and physical activity in general) can be promoted primarily through action in the local community. Poor care and insufficient material investment of the state in sports recreation are most seen in periods of economic crisis. The governments of most states are committed to top sport that provides the opportunity for faster and more widely visible promotion of state administration. Real life takes place in local communities, which is why they are primarily concerned with the development of MRSE. MRSEs are also suitable for tourism development and the promotion of local culture (Radichi, 2013; Wäsche and Woll, 2010).

4.2. SOVW brief review

The workers' sports Olympics is a decades-long project which started in the old SFR Yugoslavia. It was used to promote the health and socialization importance of recreational sport, but also as a way for the leading (in that period the only political organization), the Communist Party, to show concern for the working class. With the collapse of Yugoslavia and the great economic crisis, the idea of a workers' Olympics fell apart too. The only region of the former state where these events have been preserved is the Autonomous Province of Vojvodina. The Sports Olympics of Vojvodian Workers (SOVW) was founded in 1975 and is regularly held every 4 years in different cities. The number of participants decreased significantly compared to the first Olympics which was given maximum financial and organizational support by state-owned companies. Today, only the Vojvodian Federation of Sport for All takes serious care of the SOVW, with the financial support of the Provincial Secretariat for Sport and Youth and the local authorities of the host city. SOVW has been in crisis in recent years, which is one of the reasons for conducting this research. The aim was to evaluate the current quality of the event and identify elements for improvement.

The Hudson model (2008) is applicable for complex consideration of the quality and position of SOVW in the social environment. It analyses the following elements: 1) the mass and appeal of the event; 2) potential attraction for sponsors; 3) the possibility of creating and developing new sports, recreational and tourist facilities in the venue; 4) the incentive to build new or improve existing infrastructure; 5) adaptation of the facilities to different categories of participants and spectators; 6) raising the confidence of the local environment; 7) contribution to the specific perception of the culture and tradition of the local community (destination) in which the event is held, and 8) assistance in branding the local area as a tourist destination. These elements are the basis for considering the justification and sustainability of the SOVW, and according to Hover et al. (2016) the three main spaces for their analysis are: 1) production of the event (rights holders, organizers); co-production (participants, financiers, sponsors, media, sports organizations, volunteers), and 3) consumers (locals, non-direct visitors, NGOs, companies, agencies). These analyses are the basis for the concept of Sport for All development, primarily in local communities. Institutions responsible for implementing local strategies should continually evaluate consumer satisfaction with all the elements of the MRSE. The instrument proposed in this study (MRSEQ) can be used in such evaluations.

Previous research confirms that many recreational organizations in the world use similar quality management concepts and implement specific models of service quality measurement (Carr and De Michele, 2010; Currie and Ipson, 2002; Lee et al., 2011; Jae Ko and Pastore, 2004; and Kyungro, 2000). Most sports and recreational organizations in Serbia, however, are still not sufficiently oriented towards the implementation of quality management and the measurement of its aspects. This is especially true of measuring participants' satisfaction, thus reducing the possibility of improving the efficiency of management and internal organization (Nešić et al., 2016).

5. CONCLUSION

The majority of professional activities are performed by employees who spend long hours in passive positions which cause fatigue and have a detrimental effect on postural status. Regular physical activity is one of the most important factors for maintaining health and quality of life. A large number of employees today neglect their regular physical activity or engage in inadequate fitness programs that are attractive but do not bring health benefits (for example: high intensity training or exaggerated resistance training). Involving employees in organized recreational programs is a good way to tackle hypokinesia problems. Local governments and companies should be the main providers of such programs. Mass Recreational Sports Events (MRSE) are one of the forms for the promotion and realization of regular physical activity of employees and are widely used within the international organization Sport for All. Such events need to be valorised and the quality of their key elements measured to deliver the expected effects - health and social benefits for employees. The main role in the process of valorisation and quality management is played by users (participants in the MRSE), their perception of quality and level of satisfaction. One such event (Vojvodian Workers' Sports Olympics) was analysed in this study with the aim of developing an instrument for measuring the quality of MRSE. A valid 16-item instrument (MRSEQ) was obtained based on empirical data. It is a simple and understandable questionnaire, easily applicable in practice. Measurement results are expressed as numerical values of a single scale where higher values indicate higher quality of MRSE.

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RAZVOJ SKALE ZA PROCENU KVALITETA MASOVNIH SPORTSKO-REKREATIVNIH DOGAĐAJA

Redovna fizička aktivnost je jedan od najvažnijih preduslova za očuvanje zdravlja i kvaliteta života. Masovni sportsko-rekreativni događaji su dobar način da se promoviše fizička aktivnost. U ovom istraživanju kao primer je ocenjena Sportska olimpijada radnika Vojvodine (SORV). Osnovni cilj studije je analiza rekreativnog sportskog događaja kao masovne aktivnosti značajne za javno zdravlje. Sekundarni cilj je izrada validnog upitnika koji je primenljiv u praksi. Na uzorku od 205 učesnika 12. SORV, različitog uzrasta i pola, primenjen je instrument koji je pokazao dobru metriku. Faktorska analiza dala je stabilan jednofaktorski model sa jedinstvenom skalom za procenu kvaliteta masovnih sportsko-rekreativnih događaja. To je jednostavan i razumljiv upitnik, lako primenljiv u praksi. Rezultati ove studije su pokazali da se ocene ispitanika različitog uzrasta i pola nisu značajno razlikovale. SORV je ocenjen kao događaj srednjeg kvaliteta (ukupan rezultat iznosi 66,19% od maksimuma).

Ključne reči: *fizička aktivnost, rekreacija zaposlenih, merenje kvaliteta, masovni događaji*

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Research article

MEASURING PHYSICAL ACTIVITY, HEART RATE, ENERGY EXPENDITURE AND PERCEIVED EXERTION OF SCHOOLCHILDREN DURING RECESS ACCORDING TO GENDER AND BODY FAT

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Abstract. *The article compares the intensity of physical activity during recess in second and third grade schoolchildren according to gender and body fat percentage. Sixty-three second- and third-graders, classified with normal or high fat percentage, evaluated by bioelectric impedance (Inbody 720) participated in the study. During 27 periods of 30 minutes of recess, physical activity intensity and heart rate were evaluated with ActiGraph-GT9X accelerometers, the system for observing fitness instruction time (SOFIT) was used to measure the moderate-to-vigorous physical activity index and the energy expenditure, perceived exertion was determined using the Pictorial Children's Effort Rating Table (PCERT). The analysis of variance (ANOVA) 2x2 showed significant differences between measurements according to the percentage of normal fat compared to high, for moderate physical activity (boys: 0.003, girls: 0.005), caloric expenditure (boys: 0.005, girls: 0.005), METS (boys: 0.003, girls: 0.001), and heart rate (boys: 0.005, girls: 0.005). Due to the increased risk of diseases associated with a sedentary lifestyle, it is important to implement strategies during recess that involve more students with greater adiposity in physical activity.*

Key words: *Recess, Physical Activity, School, Gender, Body Fat.*

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INTRODUCTION

Gender equality is one of the sustainable development goals proposed by the United Nations (UN) for the reduction of extreme poverty in various dimensions, (Pérez Betancourt and Betancourt Rodríguez, 2019). Meta-analysis and systematic reviews suggest that boys and girls with sedentary lifestyles are at greater risk of presenting pathologies associated with obesity (Brooke et al., 2014; Sims, Scarborough & Foster, 2015). The World Health Organization (WHO) recommends that children between the ages of 5 to 17 spend at least 60 minutes a day practicing physical activity of moderate-to-vigorous intensity.

Although obesity is a complex and multifactorial problem (López-Mojares, 2015), basic education has been identified as an area of opportunity to promote a healthy and active lifestyle from an early age (Kim, 2012). Due to its broad coverage, it is an ideal means for promoting and developing positive attitudes and healthy habits, which serve as a basis for children and adolescents to adopt an active lifestyle as adults (Langford et al., 2015; Lonsdale et al., 2013), thus improving quality of life and reducing costs in the treatment of chronic noncommunicable diseases (Kim, 2012). The intensity of physical activity is defined as the speed or magnitude of the effort required to make an energy expenditure through the musculoskeletal system (Honas et al., 2008). Of the energy expenditure components, physical activity is the only one that can be voluntarily modified. Within school settings, the time devoted to recess has been identified as an area of opportunity to promote the practice of physical activity (Honas et al., 2008, Story, Nanney & Schwartz, 2009). Ridgers et al. (2011) report that during recess time, students can achieve up to 40% of the recommended daily physical activity. A study performed an analysis of differentiated motor behaviors between boys and girls, in which the existence of inequalities in the use and employment of the available space that harmed girls was observed (Cantó Alcaraz & Ruiz Pérez, 2005).

According to the Secretariat of Public Education (SEP for its acronym in Spanish) during the school year there are 30 minutes of recess per school day, this is established within the guidelines for the organization and operation of schools in basic education, as well as mentioning that students can use it to freely play and eat during the school day, it is also mentioned that recess must be invariably guided and supervised by school personnel, without delegating this obligation to students or external personnel (SEP, 2014).

There are different tools to assess physical activity within the school environment through the use of questionnaires, equipment, or instruments of observation, (McKenzie and van der Mars, 2015). In Mexico, research evaluating the intensity of physical activity at recess in primary schools has been performed, using the System for Observing Fitness Instruction Time (SOFIT) as an instrument (Mckenzie, 2002; Mckenzie et al., 1992). When reviewing the state of the art, moderate-to- vigorous physical activity rates during recess of 40% (43% in boys and 36% in girls) have been reported in a study conducted in 12 schools in Mexico City, with fourth and fifth grade students (Jennings-Aburto et al., 2009). Another antecedent of assessment of physical activity in recess was the research performed on 83 female high school students (ages 13 to 15) which identified lower figures (33.7%) of moderate-to-vigorous physical activity than in primary education (Medina et al., 2015).

The use of accelerometers to measure physical activity has shown greater reliability referred to as the reproducibility of the values of a measurement in repeated tests in school-age children as well as a greater validity in the measurement error (Eukelend et al., 2011; Guinhouya et al., 2013). In Mexico, a research with accelerometers evaluated physical activity of sixth grade students in Ciudad Juárez, Chihuahua during recess, finding that caloric expenditure did not present a significant difference between boys and girls (Zuñiga-Galaviz et al., 2016). These results are controversial, since studies have identified that during recess, boys perform more moderate- to-vigorous physical activity than girls (Springer et al., 2015). In this sense, evidence from studies evaluating physical activity using accelerometers in school-age children have shown results that correlate the presence of high percentage levels of body fat with a sedentary lifestyle (Laguna et al., 2013; Ferrari et al., 2016). With regard to this subject in our country, a research performed on 114 students, of 10 to 14 years of age, regarding the daily use of time, evaluated by a questionnaire, showed the following association: each hour of moderate-to-vigorous physical activity performed by a child represented a 10% decrease in the risk of obesity (categorized by the body mass index), and on the contrary, for every hour of remaining in front of television screens, a 12% risk of obesity increased (Hernández et al., 2001).

Based on a socio-ecological model, there are multiple environmental factors that can determine the intensity of physical activity of students during recess. Cross-sectional and longitudinal research mention that among these factors are the physical facilities that children have, the design of transport strategies, and the schedule promoted by the school (Skala et al., 2012; Brooke et al., 2014; Hollis et al., 2016). Therefore, the purpose of the present research is to compare the intensity of physical activity during recess of second- and third-graders according to gender and percentage of body fat.

MATERIAL AND METHODS

Participants

This research was approved and registered in the Office of Graduate Studies and Research of the Autonomous University of Baja California (Protocol # UABC-EXB-225) and was performed, under a comparative cross-sectional methodological design, with non-probability sampling for convenience (Thomas, 2001), requesting consent from the administrators, teachers, and parents of the Teniente Andrés Arreola Public Primary School, in the City of Mexicali, Baja California, Mexico, explaining the details, benefits and commitments of the research through a letter of consent, creating assessment schedules, and following the ethical principles of research involving human subjects of the Declaration of Helsinki (Puri et al., 2009).

In total, sixty-three third and fourth grade students with an average age of 7.7 ± 0.5 years (30 boys and 33 girls) participated in the study. The groups of students were classified by gender (male or female) and by percentage of body fat (normal or high), determined by means of bioelectrical impedance analysis using the Inbody 720 equipment (Biospace Inc. Korea ®), which examined the body in a segmental manner as five cylinders (four limbs and a trunk) and separately measured the impedance in these parts. Each child was evaluated barefoot, standing, and with a 30º flexion of the glenohumeral joint; eight electrodes were placed on the feet (located on the metatarsal and calcaneus bones) and on the hands (located on the second to fifth metacarpal bones and the phalanx of the thumb). The induction frequency was evaluated with 5 different intensities (5, 50, 250, 500 and 1000 kHz), in order to directly measure the amount of extracellular and intracellular water, with a fat mass estimation sensitivity of 0.1 kg (0.1%), determining the amount and percentage of body fat of each participant and classifying it as percentage of normal body fat (kg), or as percentage of high body fat (kg).

Procedures

As a cross-sectional study, when comparing fixed variables of two groups according to gender and percentage of body fat, of the total of 63 participants, four groups were classified. 1. Boys with normal body fat (n = 15), 2. Boys with high body fat percentage (n = 15), 3. Girls with normal body fat (n = 16), and 4. Girls with high body fat percentage (n = 17). The participants were evaluated at the school facility during twenty-seven recess periods lasting 30 minutes, included in the school day.

Numerical random variables associated with the intensity of the activity during recess were evaluated with the following equipment and instruments:

a. Intensity of physical activity using ActiGraph GT9X accelerometers (percentage in minutes of sedentary, light, moderate, vigorous physical activity, caloric expenditure in Kcal / 30min, intensity of physical activity in METs.
b. Average heart rate using a Polar Bluetooth Smart Heart Rate Monitor.
c. Moderate-to-vigorous physical activity index and energy expenditure rate evaluated with the system for observing fitness instruction time (SOFIT).
d. Perceived exertion through the pictorial children's effort rating table.

The methodological procedures established to determine each variable are detailed below.

Physical activity with ActiGraph GT9X Link accelerometers measurement

It is a triaxial accelerometer to measure the amount and frequency of human physical activity, (ActiGraph Inc. Pensacola, Florida, USA®) size 3.5 x 3.5 x 1 cm and 14 grams of weight, which when used measured the amount of movement through an accumulation of filtered and measured acceleration for a set period of time, stored in the device after being measured by changes in acceleration 30 times per second. The accelerometer was placed on the right hip of each student with the help of a compatible accessory, adjusting to the elastic of the clothing at the student's waist, which was worn during the 30 minutes of recess.

Heart rate measurement

Simultaneously, the Bluetooth Smart Heart Rate Monitor (Polar Inc, Finland®), compatible with the ActiGraph GT9X Link accelerometer, was utilized to determine heart rate (bpm) during the 30 minutes of recess. The data obtained for the participants was downloaded into ActiLife Software 6.13 Full Version, license 5791-4A8D-01-90FF-8CF6 (ActiGraph Inc. Pensacola, Florida, USA®), to determine the percentage time in minutes of sedentary behavior, light, moderate, vigorous physical activity and the combination of moderate-to-vigorous physical activity MVPA and average heart rate in beats per minute during recess.

Moderate-to-vigorous physical activity index measurement

In order to assess this variable, the System for Observing Fitness and Instruction Time (SOFIT) instrument was utilized (Mckenzie, 2002; Mckenzie et al., 1992). The methodology was performed with two trained observers who randomly selected 4 students (2 men and 2 women) based on the class list using the procedures in the SOFIT manual. At recess time, the participants were observed in a rotating sequence of 12 intervals for 20 seconds each, the observations being repeated throughout the entire recess, following an audio that indicated the recording times of the activity. To perform this activity, a Samsung YP-U6AB

MP3 player was utilized as an instrument. To determine the intensity, codes were utilized to classify activity levels, which allowed estimating the energy expenditure associated with physical activity. This procedure was classified into five codes: 1) Lying down, 2) Sitting, 3) Standing, 4) Walking, and 5) Very active which corresponds to running or an activity with a higher energy expenditure. From the quantification of these codes, the moderate-to-vigorous physical activity index (IAFMV by its Spanish acronym) was established, adding percentage codes 4) Walking and 5) Very active of the total time of the physical education class.

Energy expenditure rate measurement

The energy expenditure rate in kcal / kg / min was calculated from the time values in the codes: 1) Lying down, 2) Sitting, 3) Standing, 4) Walking, and 5) Very active using the rate of energy expenditure formula (kcal / kg / min) = lying fraction x 0.029 kcal / kg / min + sitting fraction x 0.047 kcal / kg / min + standing fraction x 0.051 kcal / kg / min + walking fraction x 0.096 kcal / kg / min + very active fraction x 0.144 kcal/kg/min. The two data collectors were trained following the SOFIT protocol standard, memorizing the operational definitions of the codes and learning the methodological procedures. Reliability measures were taken in 100% of the observations (Kappa statistic 0.93).

Perceived exertion measurements

The perceived exertion was determined using the Pictorial Children's Effort Rating Table (PCERT), which was developed by Yelling et al., (2002), the scale was based on the Borg CR-10 scale (Borg, 1982). Figures were added to the scale in order to adjust it to the cognitive development of the children, making it more appropriate to choose an option with a representative value for the children’s age, with scores from 1 to 10 with an average value corresponding to 5. The same student was tested again in the classroom, immediately after recess ended.

Analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS), version 23.0 for Windows (IBM Corporation, New York, USA). Two-way (2 x 2) mixed analysis of variance (ANOVA) tests were performed. The factors were: sex (men, women), adiposity groups (normal, high). The significance level was established a priori at $p \leq 0.05$ and the 95% confidence interval (95% CI) was considered appropriate.

RESULTS

Tables 1 and 2 show the mean descriptive statistics (M) and standard deviation (± SD) of the variables studied during the thirty minutes of the evaluated 27 recess periods.

Table 1 Descriptive statistics of the variables evaluated in recess of participating boys (n = 30).

Variables	Body Fat % (kg) Normal (n = 15) M ± SD	Body Fat % (kg) High (n=15) M ± SD
Sedentary behavior (%)	3.6 ± 1.6	7.3 ± 1.9
Light physical activity (%)	26.0 ± 5.0	33.9 ± 6.7
Moderate physical activity (%)	61.1 ± 6.1	52.6 ± 5.9
Vigorous physical activity (%)	9.3 ± 2.6	6.2 ± 3.1
Caloric expenditure in Kcal/30min	94.2 ± 14.2	85.47 ± 16.7
Intensity of physical activity in METs.	4.87 ± 0.8	4.30 ± 0.7
Average heart rate (bpm)	119.3 ± 10.5	111.0 ± 9.1
Moderate-to-vigorous physical activity index (%)	48.4 ± 19.6	44.3 ± 17.3
Energy expenditure rate (kcal/kg/min)	0.0710 ± 0.006	0.0653 ± 0.007
Perceived exertion	4.7 ± 1.70	4.6 ± 1.82

Note: Comparative table of the mean, standard deviation (±) for the group of boys (% of normal or high body fat (kg)). Variables measured with ActiGraph GT9X Link accelerometers (ActiGraph Inc. Pensacola, Florida, USA®), bluetooth smart heart rate monitor (Polar Inc, Finland ®), compatible with the accelerometer, classifying percentage (%) in intensity of physical activity as sedentary, light, moderate, vigorous and deriving energy expenditure in METs and Kcal / 30min. The moderate-to-vigorous physical activity index (%) resulted from the percentage sum of the codes 4) walking and 5) very active evaluated by SOFIT; as well as calculating the energy expenditure rate in kcal / kg / min from the time values in all the codes (Mckenzie et al., 1992). The perceived exertion was determined using the Pictorial Children's Effort Rating Table (PCERT) validated by Yelling et al., (2002).

Table 2 Descriptive statistics of the variables evaluated in recess of participating girls (n = 33).

Variables	Body Fat % (kg) Normal (n = 16) M ± SD	Body Fat % (kg) High (n=17) M ± SD
Sedentary behavior (%)	5.6 ± 2.6	8.9 ± 3.8
Light physical activity (%)	29.8 ± 8.2	39.5 ± 10.1
Moderate physical activity (%)	55.9 ± 5.2	45.7 ± 5.7
Vigorous physical activity (%)	8.7 ± 5.5	5.9 ± 3.3
Caloric expenditure in Kcal/30min	87.35 ± 15.47	83.95 ± 16.60
Intensity of physical activity in METs.	4.41 ± 0.5	4.0 ± 0.4
Average heart rate (bpm)	117.9 ± 10.3	109.1 ± 9.7
Moderate-to-vigorous physical activity index (%)	41.5 ± 11.3	39.3 ± 12.3
Energy expenditure rate (kcal/kg/min)	0.0665 ± 0.007	0.0601 ± 0.005
Perceived exertion	4.8 ± 1.90	4.7 ± 1.20

Note: Comparative table of the mean, standard deviation (±) for the group of girls (% of normal or high body fat (kg)). Variables measured with ActiGraph GT9X Link accelerometers (ActiGraph Inc. Pensacola, Florida, USA®), bluetooth smart heart rate monitor (Polar Inc, Finland ®), compatible with the accelerometer, classifying percentage (%) in intensity of physical activity as sedentary, light, moderate, vigorous and deriving energy expenditure in METs and Kcal / 30min. The moderate-to-vigorous physical activity index (%) resulted from the percentage sum of the codes 4) walking and 5) very active evaluated by SOFIT; as well as calculating the energy expenditure rate in kcal / kg / min from the time values in all the codes (Mckenzie et al., 1992). The perceived exertion was determined using the Pictorial Children's Effort Rating Table (PCERT) validated by Yelling et al., (2002).

The mixed 2 × 2 (groups x measurements) analysis of variance (ANOVA) test, establishing the significance level a priori at $p \leq 0.05$ and a confidence interval of 95% (CI 95%). There were no differences between groups according to gender in the studied variables. From figures 1 to 4, the study variables with an appropriate significance level in terms of measurements are observed.

Significant differences were only observed between measurements of the percentage of normal body fat compared to high body fat for the variables of % of moderate physical activity (men: 0.003, women: 0.005) figure 1, caloric expenditure in Kcal/30min (men: 0.005, women: 0.005) figure 2, intensity of physical activity in METs (men: 0.003, women: 0.005) figure 3, heart rate (bpm) (men: 0.005, women: 0.005) figure 4.

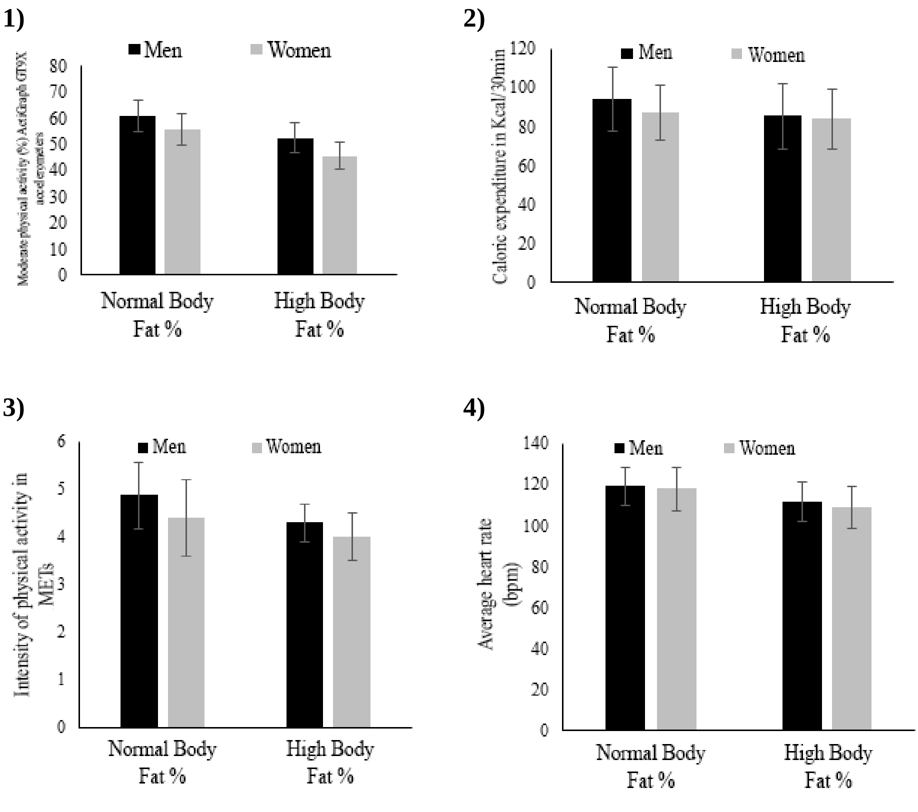

Fig. 1 Statistical inference of the variables evaluated in recess of participating boys (n = 30).

DISCUSSION

When comparing the variances in the fixed variables by gender, no significant differences were observed; however, the main finding of this research was that boys or girls with greater adiposity show less energy expenditure, less heart rate intensity, and less moderate physical activity during recess. The results of the present study reflect an equal physical activity between genders; on the other hand it is understood that there are multiple environmental factors that can determine the intensity of physical activity, energy expenditure, and perceived exertion of students in recess and during the school day (Hernández-Álvarez et al., 2010; Hollis et al., 2016; Skala et al., 2012). However, when analyzing results of studies with similar methodological procedures performed in Mexico, when using accelerometers, it can be verified that there is a significant difference between boys and girls (Zuñiga-Galaviz et al., 2016). On the other hand, it is important to identify this factor in early educational ages to prevent a sedentary lifestyle, given that the time of moderate-to-vigorous physical activity during recess for Mexican secondary school students is reported to be 33.7% (Medina et al., 2015), which are lower figures than in the present study and those reported by Zuñiga -Galaviz et al. (2016).

When analyzing more of the research performed in Mexico utilizing SOFIT as an evaluation instrument, the data of this research was corroborated, observing indices of moderate-to-vigorous physical activity between 40% to 50% of recess time (Jennings-Aburto et al. 2009; Hall-Lopez et al., 2017).

The World Health Organization recommends practicing physical activity in intensities of metabolic equivalents (METs) with a value of 3 (moderate) and 6 (vigorous) (OMS, 2014). The results of this research report average METS of between 4.0 and 4.87 during recess, which were significantly higher in boys and girls with normal than high body fat. Our results are similar to research that using physical accelerometers to measure physical activity in school-age children and associated the presence of high levels of adiposity with time spent in light activities and sedentary behavior (Laguna et al., 2013; Ferrari et al., 2016). The intensity of physical activity monitored with heart rate was significantly higher regardless of gender in students with normal adiposity compared to those classified with high body fat. The physical effort thresholds during recess time were of 58% in participants with % normal body fat and of 51% in schoolchildren with % high body fat, using the formula established by the American College of Sports Medicine (ACSM) FC max = 206.9–(age in years × 0.67) (ACSM, 2011). Regarding the perceived exertion evaluated with the pictorial children's effort rating table (Yelling et al., 2002), no significant differences were observed between groups and measurements. When comparing the heart rate figures of this study, they are not equivalent to those established by the instrument, which establishes the perceived exertion as above 4, with heart rates that correspond between 120 and 130 (bpm) (ACSM, 2011).

Recess is an ideal leisure space for playing, socializing and promoting moderate-to-vigorous physical activity, and it has been reported that during this phase of the school day children can achieve up to 40% of the recommended daily physical activity (Ridgers et al., 2011, Ceballos-López, Susinos-Rada & García-Lastra, 2019). Schools are spaces of wide coverage, environments where students during the school day develop habits and norms that govern future behavior and lifestyle (Langford et al., 2015, Stuart Rivero, López Gutiérrez & Granado Mejías, 2018). Within our context, the design and operation of educational programs and strategies that involve students with more adiposity in physical activity, could be favorable, given that they have 150 minutes per week, helping to increase energy expenditure for physical activity as recommended by the WHO (López-Fernández et al., 2020; Pérez-Trabazo et al., 2020).

CONCLUSIONS

This research has its limitations; however, it is necessary to perform future studies and take into account factors such as socioeconomic levels, public and private education, type of evaluation, and use probabilistic sampling to have extrapolated results, as well as a series of environmental variables such as sedentary behavior, to determine the affinities for the practice of physical activity by students, physical spaces and school programs, leaving a line of research to develop at recess time.

The results of this study provide important and valid information that contributes to a better understanding between recess time and the intensity of physical activity during the school day, which is useful to professionals who work in teaching in basic education when performing an educational intervention in the recreation area and indirectly contribute to the solution of problems of sedentary behavior, especially in children with more compromised health indicators, such as the one that occurs in 33.2% of school age Mexican students who are categorized as overweight and obese (ENSANUT, MC 2016).

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MERENJE FIZIČKE AKTIVNOSTI, OTKUCAJA SRCA, POTROŠNJE ENERGIJE I NAPORA UČENIKA TOKOM VELIKOG ODMORA PREMA POLU I PROCENTU TELESNE MASTI

Članak upoređuje intenzitet fizičke aktivnosti tokom velikog odmora kod učenika drugog i trećeg razreda, prema polu i procentu telesne masti. U studiji je učestvovalo 63 učenika drugog i trećeg razreda, kojima je normalan ili visok procenat telesne masti određen bioelektričnom impedansom (Inbodi 720). Tokom 27 perioda odmora od 30 minuta, intenzitet fizičke aktivnosti i broj otkucaja srca procenjeni su AcceGraph-GT9Ks akcelerometrima, a sistem za praćenje vremena podučavanja u fitnesu (SOFIT) korišćen je za merenje umerenog do snažnog indeksa fizičke aktivnosti i utroška energije, dok je napor određen pomoću tabele za ocenjivanja napora za decu (PCERT). Analiza varijanse (ANOVA) 2x2 pokazala je značajne razlike između merenja na osnovu normalnog procenta masti u poređenju sa visokim, umerene fizičke aktivnosti (dečaci: 0,003, devojčice: 0,005), utroška kalorija (dečaci: 0,005, devojčice: 0,005), METS (dečaci: 0,003, devojčice: 0,001) i pulsa (dečaci: 0,005, devojčice: 0,005). Zbog povećanog rizika od bolesti povezanih sa sedećim načinom života, važno je tokom odmora primeniti strategije koje uključuju više učenika sa većim procentom telesne masti u fizičke aktivnosti.

Ključne reči: *veliki odmor, fizička aktivnost, škola, pol, telesne masti*.

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Research article

BODY COMPOSITION, STRUCTURED PHYSICAL ACTIVITY AND NUTRITION QUALITY OF PRESCHOOL CHILDREN ACCORDING TO WEIGHT STATUS

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Abstract. *The aim of this study was to investigate the differences in body composition, involvement in structured PA and nutritional quality habits of normal weight and overweight preschool children from Serbia. Overall, 207 children (5 ± 0.87 year) participated in the study, of which 16 were excluded from the study because of incomplete data. Based on the BMI calculation, the children were divided into two groups: N1=168 normal weight (5.19 ± 0.87 year) and N2=23 overweight children (4.93 ± 0.86 year). There was no statistically significant difference between the observed groups regarding structured PA. Furthermore, no differences in nutritional status were found, underlying the importance of parents promoting good nutritional habits to their children. The preschool age provides a good opportunity for children to develop healthy eating habits in order to maintain healthy growth and development. Nutritional status monitoring in children, along with adequate physical activity, represent good preventive measures against obesity in a population. Developing and maintaining good overall lifestyle habits at this age could prevent development of some modern diseases at later stages in life.*

Key words: *NutriStep, BMI, Obesity, Physical Activity.*

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1. INTRODUCTION

Good health status, particularly in preschool children became a point of interest of many researchers world-wide, as the prevalence of overweight and obesity emerged as one of the urgent and up-rising health problems of the modern age (Drid et al., 2013; Ostojic et al., 2014; Ng, 2014). Health problems were recognized as a product of an increase in physical inactivity due to a sedentary lifestyle along with increased caloric intake and lower consumption of fruits and vegetables. Childhood obesity is associated with risk factors for later heart diseases and chronic diseases (Berenson et al., 2016), that may operate through the association between child and adult obesity (Skinner et al., 2015). Hence, the trends in child obesity should be closely monitored for its public health importance. Early childhood represents an opportunity for lifestyle interventions, as this is a critical life-stage at which children accumulate knowledge and skills around behaviors such as eating and physical activity (Wiseman et al., 2016).

The available data show that worldwide obesity has nearly tripled since 1975 (WHO, 2017), more precisely, nearly 41 million children under the age of 5 were overweight or obese in 2016. Predictions made by Lobstein and Jackson-Leach (2016) about obesity and comorbidities in school-age children in 2025 show devastating numbers, if this trend should continue. Their estimation shows increasing trends from 2010 to 2025 for global overweight prevalence in children aged 5-17 that will rise from 13.9% to 15.8%, whereas obesity alone will rise from 4.8% (76 million children) to 5.4% (91 million children). In Serbia, as one of the East European countries, the estimated population is somewhat over 7 million people, of which 56.3% of the adult population is overweight with 21.2% of them obese (Public Health Institute Serbia, 2014). To the best of our knowledge, there is only one study examining the prevalence of overweight and obesity in Serbian preschoolers 6-7 years old (Stojanovic & Belojevic, 2009) which reported 6.3% of boys and 3.8% of girls to be obese in the urban areas of South-East Serbia. Another survey reported a 13.9% prevalence of obesity in Serbian children 0-5 years old in 2014 (MICS, 2014).

Healthy eating habits and nutrition quality are essential for the normal growth and development of preschool children, as well as for preventing nutrition-related diseases later in life (Carrie et al., 2005).

The Body mass index (BMI) is one of the most common Somatic Indexes widely used in describing the weight status of children (Drid et al., 2013). Prevalence varies by region, sex, age, social position and cut-offs used. However, there is an ongoing debate about the limitations of BMI as a measure of adiposity in children, but there are also several publications that show the usefulness of this anthropometric parameter and its high correlation with other measures of adiposity (Pietrobelli et al., 1998; Mei et al., 2002).

Physical activity (PA) plays an important role in helping a child to stay fit and healthy throughout his/her lifespan. Physical activity is the most important means of improving children's health (Jin et al., 2018). Appropriately applied PA helps children have a healthy weight, achieve strong bones and muscles, improve their posture, develop cardiovascular fitness and maintain blood pressure, cholesterol and insulin sensitivity (recognized as risk factors for coronary heart disease and type 2 diabetes in adults) as well as enhance their self-esteem and build social skills. Pate & O'Neill (2012) emphasize that the recommendations from health organizations regarding the guidelines for the type and the amount of PA for preschool children differ. However, they all agree and recommend about 3 hours of total PA per day for children 3 to 5 years old. Nevertheless, there is a lack of research in preschool children regarding nutritional status and PA.

Based on the above mentioned, the aim of this study was to investigate the differences in body composition, involvement in structured PA and nutritional quality habits of normal and overweight preschool children.

2. METHODS

2.1. Participants

The evaluation took place between September and November 2017 with stratified (geographically) random sampling which was used in this cross-sectional study. Five state kindergartens were selected on a proportional basis, with 15-30% of each respective kindergarten age group being sampled. Around 90% of the children in Subotica attend preschool. The head principal of the kindergartens was contacted, and the aims of the study explained to both the kindergarten nurses and educators, as well as school administrators. Once a kindergarten had agreed to participate in the study, letters to parents were distributed. All participants and parents were fully informed verbally and in writing about the nature and demands of the study. All of the participants and parents gave their informed consent and volunteered to participate in the study with the approval of the College's Ethical Advisory Commission in accordance with the Declaration of Helsinki. The parents were informed that they could withdraw a child from the study at any time, even after giving their written consent. Overall, 207 children (5 ± 0.87 year) participated in the study, of which 16 were excluded from the study because of incomplete data. Based on the BMI calculation (Cole et al., 2000) that all children over the 0.91 percentile are considered to be overweight – the children were divided into two groups: N1=168 normal weight (5.19 ± 0.87 year) and N2=23 overweight children (4.93 ± 0.86 year). The survey on child nutrition was filled out by the parents (in 75% of cases by the mother).

2.2. Experimental design

Each child underwent a one-day testing session, where anthropometric assessment was carried out. Height was measured using a mobile stadiometer (Model 202, Seca, Birmingham, UK) to the nearest 0.1 cm, while body mass was obtained to the nearest 0.1 kg using a bioelectric impedance analysis InBody230 (Biospace Co., Ltd, Corea). The participants were measured in private by experts of the respective gender, in their underwear only, and in the same state of hydration and nourishment after voiding. All anthropometric measurements were taken between 9 and 11 a.m. after an overnight fast of between 10 and 12 h. BMI was calculated as weight (kg)/height $(m)^2$. Skinfold thickness at three sites (abdominal, subscapular and triceps) were obtained using a Harpenden caliper (British Indicators Ltd., St. Albans, UK). The landmarks were identified and measured according to Wilmore & Behnke (1969), with the median of three measurements used to represent skinfold thickness (Cronbach's α=0.99). The experimental design was approved by institutional Ethics committee.

2.3. Body composition

Body composition was assessed with a bioelectric impedance analysis InBody230 (Biospace Co., Ltd, Corea), where muscle mass, body fat and body fat% were obtained. Measurements were carried out through a given protocol for children by the manufacturer with a frequency of 50 kHz.

2.4. Nutritional questionnaire and sports recreational involvement of children

Nutritional habits were estimated through a standardized Nutrition screening tool for preschoolers - the NutriStep® questionnaire (Ontario, Canada), with previously confirmed reliability of the screening tool (Simpson et al., 2017). Nutrition risk screening through a valid and reliable 17-item questionnaire is the process of identifying factors known to be associated with dietary or nutritional issues. The purpose of nutrition risk screening is to identify issues before they become serious or cannot be reversed and to refer those at risk to appropriate tests and treatment. The NutriStep® questionnaire provides early identification of potential nutrition issues and attributes to food and fluid intake, physical growth and development, factors affecting food intake and eating behaviors as well as physical activity and sedentary behavior. For each template, the coding for each response on the questionnaire was provided within a spreadsheet, where the overall score <20 is classified as low risk and Rank 1; scores 21-25 were classified as medium risk and Rank2; and scores >26 were classified as high risk and Rank 3. Moreover, parents were asked if the children were involved in structured PA. They had to answer simply with a yes or no.

2.5. Statistical Analysis

All data are presented as mean values and standard deviations. From descriptive statistics, for each variable, measures of central tendency (arithmetic mean) dispersion (standard deviation), minimum, maximum and standard error were calculated. For comparative statistics, the T test for independent samples was used for parametric data analysis, and the Mann-Whitney test was applied for nonparametric variables. The level of significance was set at $p \leq 0.05$.

3. RESULTS

Table 1 shows the results of the body composition for normal weight and overweight children. There is a statistically significant difference found in all observed variables. On average, overweight children have nearly 5 kg in body weight more than their peers. Furthermore, the differences in the average values for body fat between the observed groups is around 3.5 kg, and for muscle mass only 1 kg in favor of the overweight group of children. The greatest difference in the average values for skin folds is observed for the abdomen.

Table 1 Results for body composition of obtained groups according to weight status

	Normal weight (n=168)			Overweight (n=23)			
	Mean ± SD	Min	Max	Mean ± SD	Min	Max	p
Body weight (kg)	19.63 ± 2.86	14.1	29.1	24.96 ± 3.46	19.1	31.2	0.00
Abdominal skinfold (mm)	7.79 ± 3.05	3.87	18.80	16.21 ± 4.65	6.47	26.13	0.00
Subscapular skinfold (mm)	5.62 ± 1.21	3.60	9.40	9.82 ± 2.75	6.00	17.33	0.00
Triceps skinfold (mm)	8.62 ± 2.02	5.20	14.27	12.93 ± 2.80	7.00	19.80	0.00
Muscle mass (kg)	7.35 ± 1.47	4.1	11.9	8.45 ± 1.79	5.7	11.5	0.00
Body fat (kg)	3.79 ± 1.14	1.4	7.3	7.31 ± 1.41	5.3	10.0	0.00
Body fat (%)	19.29 ± 5.01	8.2	32.0	29.46 ± 4.99	20.3	40.2	0.00

The results for the involvement of children in structured activities are presented in Table 2. There was no statistically significant difference between the observed groups regarding structured PA. Normal and overweight children were equally included in some kind of structured activities.

Table 2 Results for involvement in sports-recreational activities for groups according to weight status

	Normal weight (n=168)	Overweight (n=23)	p
Included in structured PA	124 (73.8%)	17 (73.9%)	0.99^{*}
Not included in structured PA	44 (26.2%)	6 (26.1%)	

*Z= -.011

The overall results of the nutrition quality in preschool children, assessed through the NutriStep® questionnaire, showed no statistically significant difference between formed groups of participants (Table 3). Furthermore, the Mann-Whitney test showed no differences between ranks as well. More than 50% of normal weight children were in Rank 1, but the distribution of the results in the Ranks was significantly more equal in the group of overweight children.

Table 3 NutriStep® results for groups according to weight status

NutriStep® Rank	Normal weight (n=168)	Overweight (n=23)	p
Rank 1	90 (53.3%)	9 (39.1%)	
Rank 2	50 (29.6%)	7 (30.4%)	0.13^{*}
Rank 3	29 (17.2%)	7 (30.4%)	
Total Score	20.33 (±5.36)	21.52 (±6.83)	0.33^{**}

*Z= -1.528

**t= -.971

4. DISCUSSION

The presented study observed body composition, the level of PA and nutritional status in preschool children from Subotica, Serbia. From the results obtained, 12.04% (N=23) of the participants were found to be overweight from the overall number of participants (N=191). Some other studies also noted excessive weight and obesity in pre-school children (De Onis et al., 2010; Martorell et al., 2000; Biehl et al., 2013), confirming the sternness of this rising problem at this age. An increased number of overweight or obese people due to increased intake of saturated fats, free sugars, refined foods and alcohol, followed by changes in physical activity and stress level, represents a trend in modern and developing societies (Popkin, 1994). As the society makes progress and develops, it seems that this frontier of being overweight and obese is brought closer to a younger population. So far it has been confirmed that children look up to the elderly in their surroundings, and a few studies have already confirmed the parental and environmental influence on children's eating habits (Sigman-Grant et al., 2013; Zarnowiecki et al., 2011)

Body composition in its structure includes skeletal muscle, fatty tissue (subcutaneous fat tissue and visceral tissue), bone tissue, visceral organs and the brain. There are numerous factors that could contribute to a change in body composition, such as genetics, environmental factors, energy consumption, etc., (Kopelman, 2000). However, it is assumed that overweight or obesity are more often caused by a combination of different factors. Evaluating body fat and muscle mass in overweight and normal weight preschool children in this study, a statistically significant difference was found in all the observed body composition variables in favor of the normal weight group of children. The differences obtained in the results were expected, given that groups were formed according to the body mass index based on the recommendations made by Cole et al. (2000).

Significant factors of obesity often include nutritional habits (nutritional adequacy, food portions, and food quality) and PA. By monitoring the dietary habits of children, the authors tried to determine the differences between overweight and normal weight children. Based on the results obtained, it can be noticed that there are no statistically significant differences in nutritional status in preschool children according to their weight status. At this age parents have a unique role in promoting healthy behaviors to their children (Jaballas et al., 2011), and parents were the ones answering the nutritional questionnaire. Furthermore, the lack of differences between groups could be justified with a very small sample size of overweight children. However, when observing percentage values, it can be noticed that a significantly higher percentage of normal weight children belong to Rank 1 (low nutritional issues risk), whereas a significantly higher percentage of overweight children belong to Rank 3 (high nutritional issues risk). Several studies (Lamb and Ogden, 2015; Nalty et al., 2013) similarly found no association between obesity and food insecurity among preschool children, justifying this finding with more direct parental knowledge of good nutritional habits in younger children compared to older children. Overall, the obtained results on current dietary behaviors and practices of preschool children from Subotica could be evaluated as having a satisfactory nutritional level.

Monitoring physical activity with adequate measuring instruments is of a high importance for obtaining valid information. Present research did not monitor physical activity directly; however, based on the questionnaire, information was obtained on how many children are attending structured physical activity in their spare time. The data confirmed no statistically significant difference between the formed groups of participants, whereas very similar percentage values were reported. About 74% of the children are involved in structured PA in their spare time. Structured PA of children positively reflects on their health status, in addition to children’s learning about sports skills, which is very important for leading them to a certain sport discipline later. The data on the inclusion of children in structured physical activity was not sufficient enough to find out what the overall child's PA was during the day.

Limitations of the present study that must be taken into consideration include the fact that the observed groups of children were uneven in numbers. In addition, no direct measurement of the level of PA among children was performed. Additional research is needed to include a larger uniform pattern of groups of children by levels of nutrition, as well as direct measurement of the level of PA of children of this age with an accelerometer or a pedometer. Furthermore, a longitudinal study with more measures of developmental status, body composition, nutritional habits as well as the level and structure of PA could give more substantial evidence regarding weight status in preschool children.

5. Conclusion

Differences in body composition between normal weight and overweight preschool children were found. However, there were no differences regarding the level of structured PA. Furthermore, no differences in nutritional status were found, underlying the importance of parents promoting of good nutritional habits to their children. The preschool age represents a good opportunity for children to develop healthy eating habits in order to maintain healthy growth and development. A monitored nutrition status in children, along with adequate physical activity, represents good preventive measures against obesity in a population. Developing and maintaining good overall lifestyle habits at this age could prevent the development of some modern diseases at later stages of life.

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TELESNA KOMPOZICIJA, STRUKTURIRANA FIZIČKA AKTIVNOST I KVALITET ISHRANE U ODNOSU NA TEŽINSKI STATUS PREDŠKOLSKE DECE

Cilj ovog istraživanja bio je da se ispitaju razlike u telesnoj kompoziciji, uključenosti dece u strukturiranu fizičku aktivnost (FA), kao i kvalitet ishrane dece predškolskog uzrasta sa normalnom i prekomernom telesnom težinom sa područja Srbije. U istraživanju je učestvovalo ukupno 207 dece (5 ± 0,87 godina), od kojih je 16 isključeno iz studije zbog nepotpunih podataka. Na osnovu izračunatog ITM (indeksa telesne mase), deca su podeljena u dve grupe: N1=168 normalne težine (5,19 ± 0,87 godina) i N2=23 dece sa prekomernom telesnom težinom (4,93 ± 0,86 godina). Nisu pronađene statistički značajne razlike između posmatranih grupa u pogledu strukturirane FA, ni razlike u statusu uhranjenosti posmatrane dece, što ukazuje na važnost roditelja i promocije dobrih prehrambenih navika svojoj deci. Predškolski uzrast pruža dobru priliku deci da steknu zdrave navike u ishrani kako bi održali zdrav rast i razvoj. Praćenje nutritivnog statusa kod dece, uz adekvatnu fizičku aktivnost, predstavljaju dobre preventivne mere protiv gojaznosti u populaciji. Razvijanje i održavanje dobrih opštih životnih navika u ovom uzrastu može sprečiti razvoj nekih savremenih bolesti u kasnijim fazama života.

Ključne reči: *NutriStep anketa, ITM, gojaznost, fizička aktivnost*.

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Research article

INFLUENCE OF MORPHOLOGICAL CHARACTERISTICS ON THE PARAMETERS OF HEALTH-RELATED FITNESS IN OVERWEIGHT AND OBESE BOYS

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Abstract. *The aim of this study was to determine the influence of morphological characteristics on the health–related fitness parameters in overweight and obese eight-year-old boys. The research involved 314 boys who attended second grade in the cities of South-East Serbia. The parameters of longitudinal (3), transversal, (3) circular dimensions (3), and body mass and measurement of subcutaneous adipose tissue (3) were used to assess morphological characteristics. Health-related fitness parameters were determined using tests to assess muscle fitness, body composition and cardiorespiratory fitness. Regression analysis was used to determine the influence of morphological characteristics on the parameters of health-related fitness. The results of the research indicate that there is a statistically significant influence (p=.000) of morphological characteristics on most parameters of health-related fitness. No statistically significant effect was found in the forward bend - backward bend - throw test ∑ in the studied sample.*

Key words: *Fitness Parameters, Morphological Characteristics, Health-Related Fitness, Cardiorespiratory Fitness*

INTRODUCTION

Health-related physical fitness implies the physical fitness of children and adults, i.e. those components that are related to their health status, such as body composition, muscle fitness, flexibility, cardiorespiratory fitness, and strength (Corbin, Pangrazi, & Franks, 2000).

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In addition to this type of fitness, there is also skill-related physical fitness, which includes those skills related to achievements in sports (balance, coordination, agility, speed, strength, and reaction time) (Jarani, Grøntved, Muca, Spahi, Qefalia, Ushtelenca et al., 2016). The health-related physical fitness of children and adolescents is one of the main indicators of their current health status, but also of their health status in adulthood (Armstrong, Lambert, & Lambert, 2017). A large number of factors affect the occurrence of overweight and obesity in childhood (Reilly, Armstrong, Dorosty, Emmett, Ness, Rogers et al., 2005), besides genetic predispositions, but above all these conditions are caused by a positive energy balance of calorie intake, which is higher than the energy consumption (Kumar & Kelly, 2017). The World Health Organization (WHO, 2016) states that there is a prevalence of overweight and obese children in all countries. However, the most of obese children live in developing countries where the growth rate is as much as 30% higher than in developed countries (WHO, 2016). The number of obese children is increasing, and this trend has been more pronounced in the last 20 years (Skinner & Skelton, 2014; Anderson, 2018). The incidence of overweight and obesity in Europe changed from 20% between 1999 and 2006, to 22.9% between 2011 and 2016. In the United States there is a steady increase in the prevalence of overweight as well as obesity among children (Ogden, Carroll, Lawman, Fryar, Kruszon-Moran, Kit, & Flegal, 2016), with a significant increase in extreme obesity in children aged two to five in 2013 and 2014, a trend that is continuing in other age groups (Skinner, Ravanbakht, Skelton, Perrin, & Armstrong, 2018). When it comes to the world population, it is estimated that 41 million children under the age of 5 are overweight or obese (WHO, 2018). Between 1975 and 2016, the global prevalence of obesity increased from 5 to 50 million in girls and from 6 to 74 million in boys (Abarca-Gómez, Abdeen, Hamid, Abu-Rmeileh, Acosta-Cazares, Acuin et al., 2017). Obesity among children and adolescents in Serbia is taking on epidemic proportions, as is the case with other countries in transition (Ostojić, Stojanović, Stojanović, Marić, & Njaradi, 2011). In 2015, the prevalence of obesity among Serbian children aged six to nine was 23.1% (Đorđić, Radisavljević, Milanović, Božić, Grbić, Jorga, & Ostojić, 2016), which is in the range of countries with a high degree of obesity. The greatest impact on the increase of obesity prevalence in children and adolescents, in addition to inadequate and excessive nutrition, has a reduced and insufficient physical activity: children and adolescents often spend a huge amount of their leisure time on writing homework, watching TV, using a computer and their smartphones, that is, they spend most of their time in sedentary activities (Song, Gong, Ding, Yuan, Zhang, Feng et al., 2019). The World Health Organization (WHO, 2010) has given their recommendations concerning physical activities, according to which children should be physically active (activities of moderate or high intensity) for at least 60 minutes a day. The results of some studies indicate that a large number of children are not physically active enough and do not meet the guidelines given by the WHO (Martins, Ricardo, Mendonca, de Rosa, da Gama Bastos, Coll, & Bielemann, 2018; Wang, Hsieh, Hsueh, Liu, & Liao, 2019), and that boys are physically more active than girls (Glinkowska, & Glinkowski, 2018).

Given that, in children and adolescents fitness is an important indicator of their current and future health status (Colley, Clarke, Doyon, Janssen, Lang, Timmons, & Tremblay, 2019), it is a worrying fact that the parameters of health-related fitness of children and adolescents stagnate over time, i.e. there is a decline in the levels of certain fitness abilities such as flexibility (Costa, Costa, Reis, Ferreira, Martins, & Pereira, 2017), cardiorespiratory fitness (Colley et al., 2019) and muscle strength and endurance (Dong, Lau, Dong, Zou, Yang, Wen et al., 2019). Studies that have addressed this issue suggest that being overweight significantly affects athletic performance, especially jumping performance, running speed, and maximum oxygen consumption (Moncef, Said, Olfa, & Dagbaji, 2012), as well as that children who are taller and have higher values of body mass tend to achieve higher strength values, and children with lower values of body mass achieve better results when it comes to aerobic endurance (Vandendriessche, Vandorpe, Coelho-e-Silva, Vaeyens, Lenoir, Lefevre, & Philippaerts, 2011). The aim of the research is to determine the influence of morphological characteristics on the health-related fitness parameters in overweight and obese eight-year-old boys.

METHODS

Sample of participants

For the purpose of the research, a sample of 314 boys (Age: 8.9±0.15 years, Body height: 137.70±5.93 cm, Body mass: 41.90±5.13 kg), who attended the second grade, from the territory of the cities of Niš, Paraćin, Bela Palanka, Leskovac and others, was used. The sample was taken from the populations of overweight and obese boys tested within the project "Anthropological characteristics of children in southeastern Serbia - state, changes and trend", which is implemented by the Faculty of Sports and Physical Education of the University of Niš.

The participants were selected based on the specific body mass index (BMI) values developed by Cole, Bellizzi, Flegal, & Dietz (2000) for children and adolescents 2 to 18 years of age, and according to these values, overweight and obese boys who participated in the study had BMI>18.44 kg/m^2. The research was conducted in accordance with the Declaration of Helsinki (WMA, 2013), and in order for a child to participate in the research, the consent of a parent or guardian was required.

Measuring instruments

For the needs of the research, the parameters for the assessment of morphological characteristics and the parameters for the assessment of the health-related fitness of boys of the stated age were tested.

From the area of morphological characteristics, the following parameters were measured: body height (in cm), arm length (in cm), leg length (in cm), shoulders width (in cm), pelvic width (in cm), hip width (in cm), body mass (in kg), mean chest circumference (in cm), forearm circumference of the outstretched arm, thigh circumference (in cm), skinfold of the upper arm, back and abdomen (in mm). Techniques proposed by the International Biological Program (Weiner & Lourie, 1969) were used for the assessment of the above mentioned morphological characteristics.

The following tests were used for the assessment of fitness parameters: the plyometric jump (in cm) was used to assess muscle fitness, i.e. explosive strength of the legs (Nazarenko, 2000) and the forward bend - backward bend - throw test ∑ (in cm) (Kostić, Đurašković, Pantelić, Živković, Uzunović, & Živković, 2009) to assess explosive strength of the arms, shoulders, and trunk. The body fat percentage was determined using the values of the skinfolds of the triceps, abdomen and back, using the equation given by Slaughter, Lohman, Boileau, Horewill, Stillman, Van Loan, & Bemben (1988). BMI was determined by using the ratio of body mass to body height (kg/m^2). Cardiorespiratory fitness was determined using the 20 m shuttle run test, and the validity of this test has been confirmed in earlier studies (Leger & Lambert, 1982; Leger, Mercier, Gadoury, & Lambert, 1988; Council of Europe, 1993). An algorithm according to Leger & Gadoury (1989) was used to calculate the maximum oxygen consumption (VO_2max). The parameters analyzed in the study are Absolute VO_2max (L) and Relative VO_2max (ml/kg/min).

Data processing

Data processing was performed using the statistical package Statistics 6.0. Basic descriptive parameters were calculated: Mean, Minimum Value (Min), Maximum Value (Max), Standard Deviation (SD), Range. Regression analysis was used to determine the influence of morphological characteristics on the parameters of health-related fitness.

RESULTS

Table 1 shows the values of descriptive parameters of morphological characteristics and health-related fitness parameters in overweight and obese eight-year-old boys.

Table 1 Descriptive statistics of morphological characteristics

	Mean	SD	Min	Max	Range
Body height	137.70	5.93	120.00	156.20	36.20
Leg length	76.56	4.37	63.20	98.20	35.00
Arm length	57.73	3.04	47.20	69.30	22.10
Shoulder width	31.96	1.62	27.50	37.20	9.70
Pelvic width	23.39	1.45	19.00	31.40	12.40
Hip width	25.96	1.37	22.30	30.00	7.70
Body mass	41.90	5.13	30.55	56.50	25.95
Chest circumference	68.50	4.81	45.20	85.50	40.30
Upper arm circumference	21.41	1.68	15.50	32.20	16.70
Thigh circumference	42.28	3.00	33.30	51.00	17.70
Upper arm skinfold	16.32	4.20	6.80	33.20	26.40
Back skinfold	14.40	4.48	6.50	30.80	24.30
Abdomen skinfold	19.53	6.10	6.40	43.20	36.80
Plyometric jump	17.88	5.51	4.00	48.00	44.00
Forward bend - backward bend - throw test ∑	56.17	24.17	12.00	154.00	142.00
Body fat %	30.85	5.19	19.77	45.92	26.15
BMI	21.51	1.63	19.18	25.12	5.94
VO_2max L	1.79	0.02	1.76	1.96	0.20
VO_2max ml	44.33	5.09	32.75	59.88	27.13

Legend: Mean - mean value, SD - standard deviation, Min - minimum value, Max -maximum value, BMI - Body Mass Index, VO_2max L - absolute oxygen consumption, VO_2max ml - relative oxygen consumption.

Table 2 shows the results of the influence of morphological characteristics on the parameters of muscle fitness in overweight and obese eight-year-old boys.

Table 2 Influence of morphological characteristics on muscle fitness

	Morphological characteristics – the plyometric jump				Morphological characteristics – the forward bend - backward bend - throw test ∑			
	R	Part R	Beta	p	R	Part R	Beta	p
Body height	-.02	-.05	-.13	.413	-.02	.10	.28	.089
Leg length	.03	.06	.13	.266	-.05	-.07	-.15	.221
Arm length	.01	.01	.02	.817	-.04	-.02	-.02	.813
Shoulder width	.03	.14	.20	.012*	-.04	-.01	-.00	.973
Pelvic width	-.09	.01	.01	.877	-.06	-.01	-.01	.937
Hip width	-.07	-.00	-.01	.935	-.04	.01	.01	.896
Body mass	-.14	-.03	-.09	.609	-.06	-.08	-.26	.150
Chest circumference	-.18	-.10	-.15	.097	-.04	.03	.05	.589
Upper arm circumference	-.15	-.04	-.06	.449	-.02	.05	.08	.366
Thigh circumference	-.06	.11	.15	.061	-.05	-.01	-.00	.976
Upper arm skinfold	-.17	.01	.01	.889	-.04	-.01	-.01	.852
Back skinfold	-.28	-.12	-.18	.039*	-.05	.01	.01	.946
Abdomen skinfold	-.24	-.07	-.09	.247	-.04	.01	.00	.981
	R= .35 R^2= .12 F= 3,18 p=.000**				R= .13 R^2 = .17 F= 0,40 p=.967			

Legend: R - multiple correlation coefficient of the criterion variable and predictor system, Part R - partial correlation, Beta - standard partial regression coefficient of each predictor variable with a criterion; F - F-test; p - level of statistical significance; ** p<.01; * p<.05.

Based on the obtained results (Table 2), it can be concluded that there is a statistically significant influence of morphological characteristics on the values of the plyometric jump at the multivariate level (p=.000). The variables shoulder width and back skinfolds have a statistically significant effect on the plyometric jump (p=.012 and p=.039, respectively). Other morphological characteristics do not have a statistically significant effect on the plyometric jump of eight-year-old boys.

Based on a further analysis of Table 2, which shows the results of the influence of the system of morphological characteristics on the result of the forward bend - backward bend - throw test ∑ for eight-year-old participants, it can be concluded that there is no statistically significant influence (p=.967).

Table 3 presents the results of the influence of morphological characteristics on body fat and BMI of overweight and obese boys.

The results of individual regression coefficients indicate that the variable upper arm skinfold (p=.000) has the greatest influence on the body fat percentage in overweight and obese boys, followed by the back skinfold (p=.000), and upper arm circumference (p=.037).

The analysis shows that there is a statistically significant influence of morphological characteristics on BMI at the multivariate level (p=.000, Table 3). It can be concluded that body height (p=.000) and body mass (p=.000) have the greatest influence on BMI, based on the results of individual regression coefficients, followed by hip width (p=.001) and upper arm circumference (p=.002). Other morphological characteristics do not have a statistically significant effect on the BMI of eight-year-old boys.

Table 3 Influence of morphological characteristics on body fat and BMI

	Morphological characteristics - Body fat				Morphological characteristics - BMI			
	R	Part R	Beta	p	R	Part R	Beta	p
Body height	.20	-.03	-.01	.596	.18	-.97	-1.101	.000**
Leg length	.13	-.03	-.01	.631	.09	.04	.01	.508
Arm length	.14	-.03	-.01	.616	.18	-.09	-.01	.100
Shoulder width	.22	-.07	-.01	.231	.34	-.06	-.01	.264
Pelvic width	.45	.06	.01	.332	.53	-.06	-.01	.316
Hip width	.41	.03	.01	.592	.53	.19	.04	.001**
Body mass	.52	.03	.01	.611	.73	.98	1.567	.000**
Chest circumference	.47	-.02	-.00	.707	.64	.08	.013	.164
Upper arm circumference	.50	.12	.02	.037*	.62	.18	.026	.002**
Thigh circumference	.38	.02	.01	.790	.57	.04	.006	.463
Upper arm skinfold	.87	.96	.53	.000**	.48	.03	.004	.551
Back skinfold	.88	.95	.57	.000**	.63	.00	.001	.932
Abdomen skinfold	.68	.01	.01	.917	.55	.03	.004	.644
	R= .99 R^2= .98 F= 149,60 p=.000**				R= .99 R^2= .99 F= 2464,10 p=.000**			

Legend: R - multiple correlation coefficient of the criterion variable and predictor system, Part R - partial correlation, Beta - standard partial regression coefficient of each predictor variable with a criterion; F - F-test; p - level of statistical significance; ** p<.01; * p<.05.

Table 4 shows the results of the influence of morphological characteristics on cardiorespiratory fitness (absolute and relative oxygen consumption) in boys aged eight.

Table 4 Influence of morphological characteristics on cardiorespiratory fitness

	Morphological characteristics – VO_2max L				Morphological characteristics – VO_2max ml/kg/min			
	R	Part R	Beta	p	R	Part R	Beta	p
Body height	.56	-.01	-.00	.995	-.79	-.15	-.09	.007**
Leg length	.46	-.05	-.07	.412	-.65	-.03	-.01	.623
Arm length	.50	.06	.08	.277	-.66	.11	.04	.055*
Shoulder width	.48	.03	.02	.657	-.64	.07	.02	.235
Pelvic width	.52	.09	.11	.127	-.72	.06	.02	.279
Hip width	.52	-.06	- .08	.282	-.78	-.15	-.05	.009**
Body mass	.67	.32	.79	.000**	-.98	-.81	-.84	.000**
Chest circumference	.47	-.07	- .08	.245	-.74	-.09	-.03	.115
Upper arm circumference	.38	-.12	- .12	.042*	-.70	-.19	-.06	.001**
Thigh circumference	.42	.02	.02	.719	-.65	-.03	-.01	.605
Upper arm skinfold	.22	.03	.03	.591	-.39	-.02	-.01	.682
Back skinfold	.29	-.04	- .04	.474	-.52	-.01	-.00	.929
Abdomen skinfold	.24	-.06	- .05	.327	-.48	-.05	-.02	.342
	R= .86 R^2= .46 F= 20,31 p=.000**				R= .98 R^2= .96 F= 613,29 p=.000**			

Legend: R - multiple correlation coefficient of the criterion variable and predictor system, Part R - partial correlation, Beta - standard partial regression coefficient of each predictor variable with a criterion; F - F-test; p - level of statistical significance; ** p<.01; * p<.05.

It can be stated that there is a statistically significant influence of morphological characteristics on the absolute oxygen consumption at the multivariate level (p=.000, Table 4). Based on the results of individual regression coefficients, it can be stated that the variable body mass and upper arm circumference have a statistically significant influence on absolute maximum oxygen consumption (p=.000 and p=.042, respectively). Other morphological characteristics do not have a statistically significant effect on the criterion variable in boys aged eight.

Based on the results of te regression coefficients, the variable body mass (p=.000), then upper arm circumference (p=.001), body height (p=.007) and hip width (p=.009) have a statistically significant effect on relative VO_2max (p=.000, Table 4). Other morphological characteristics do not have a statistically significant effect on the criterion variable of relative oxygen consumption in boys aged eight.

DISCUSSION

The obtained results of the influence of morphological characteristics on the parameters of muscle fitness indicate that shoulder width and back skinfold have the greatest influence on the explosive strength of the legs (the plyometric jump). Subcutaneous adipose tissue and transversal dimensionality affect the performance of plyometric jumping (Ara, Moreno, Leiva, Gutin, & Casajús, 2007; Đorđević, Pantelić, Kostić, & Uzunović, 2015) by disrupting and making it difficult to perform tasks that require body displacement (Živković, Ranđelović, Đorđević, Pantelić, & Malobabić, 2018). Excess subcutaneous adipose tissue is an additional load that needs to be moved during certain motor tasks, which has been determined in other studies (Siahkouhian, Mahmoodi, & Salehi, 2011; Sepúlveda, Méndez, Duarte, Herrera, Gómez-Campos, Lazari, & Cossio-Bolanos, 2018). In contrast to the determined statistically significant influence of morphological characteristics on the explosive strength of the legs, the effect on the explosive strength of the arms, i.e. on the forward bend - backward bend - throw test ∑, is missing (Table 2). Considering the fact that in the forward bend - backward bend - throw test ∑ is not necessary to lift and move your own body in space, which absolutely explains the fact that excess body weight is not an obstructively factor. Children, adolescents, as well as overweight and obese adults, tend to achieve better results than those of normal weight when it comes to explosive arm strength, i.e. higher body mass values have a positive effect on motor tasks such as the athletic throw (the shot put, hammer throw, discus) (Živković et al., 2018). In the current research such results have not been obtained, and the reason for this might be the fact that sensitive periods for this motor ability appear at a later age (Balyi & Way, 2005), and also that morphological characteristics do not affect certain fitness parameters in prepuberty, which was the conclusion of some authors (Silva, Birkbeck, Russel, & Wilson, 1984; Ball, Massey, Misner, Mckeown, & Lohman, 1992).

The variables skinfold of the upper arm and back, just like the circumference of the upper arm, have a statistically significant effect on body fat percentage in overweight and obese boys (Table 3). The upper arm and back skinfolds directly affect the result of the body fat percentage and, accordingly, are an integral part of the equation used to calculate it (Slaughter et al., 1988). The evidence of a strong correlation between these variables is also found in other studies that used ultrasound methods to determine the correlations of subcutaneous fat and body fat percentage (Leahy, Toomey, McCreesh, O'Neill, & Jakeman, 2012; Singh, Varte, & Rawat, 2014). Based on the obtained results it can be concluded that body height, body mass, then hip width and the upper arm circumference have the greatest influence on the body mass index (Table 3). Body height and body mass directly affect the body mass index, and are an integral part of the BMI equation (WHO, 1997). Transversal skeletal dimensionality and voluminosity in overweight and obese boys affected the body mass index value and it could be assumed that participants with higher values of adipose tissue would have higher values of transversal dimensionality (especially when it comes to hip width) and voluminosity (especially upper arm circumference and body mass), and therefore the values of the body mass index will be influenced by them. The similar results were found in the study of Đorđević & Kostić (2016).

Further analysis of the results shows that there is a statistically significant influence of morphological characteristics on the cardiorespiratory system. The results indicate that body mass and upper arm circumference (Table 4) have the largest influence on absolute oxygen consumption (VO_2max L): boys with higher values of body mass have higher values of absolute oxygen consumption, which suggests that body mass directly affects VO_2max L (Đošić, Bratić, Jezdimirović, Purenović-Ivanović, Živković, & Bratić, 2019; Johansson, Brissman, Morinder, Westerståhl, & Marcus, 2020). Excessive body mass imposes an unfavorable load on cardiac function and oxygen intake by working muscles, and when obese people have a higher value of absolute oxygen consumption, they indicate a higher cardiac load during physical activity. Overweight and obese children are insufficiently physically active and experience more stress during physical activity than normally nourished children, which affects cardiorespiratory fitness (Chatterjee, Chatterjee, & Bandhopadhyay, 2005). This result speaks in favor of the fact that obese people are exposed to higher metabolic requirements due to the higher values of body mass, which results in higher values of absolute oxygen consumption.

A more objective method for assessing the state of cardiorespiratory fitness in overweight and obese boys is relative oxygen consumption. Variables for estimating longitudinal and transversal skeletal dimensionality, as well as voluminosity, have a statistically significant effect on relative VO_2max. The results indicate that higher values of the mentioned dimensions will negatively affect relative oxygen consumption, and this is confirmed by other studies (Chatterjee et al., 2005; Živković et al., 2018; Johansson et al., 2020). A human body loaded with fat deposits cannot accept an adequate amount of oxygen and pass it to the working muscles, and the reduced use of oxygen by adipose tissue also reduces the total VO_2max. The biggest negative predictor of obesity is the level of cardiorespiratory endurance. It has been found that the risk of obesity decreases by as much as 10% with an increase in VO_2max of only 1 ml/kg/min (Ortega, Labayen, Ruiz, Kurvinen, Loit, Harro et al., 2011).

CONCLUSION

The aim of the study was to determine the influence of morphological characteristics on the parameters of health-related fitness in overweight and obese boys aged eight. Based on the obtained results it was determined that there is a statistically significant influence of morphological characteristics on the parameters of health-related fitness in each of the selected variables (the plyometric jump, Body fat %, BMI, VO_2max L and VO_2max ml), except for the variable the forward bend - backward bend - throw test $\sum$.

Excess body mass and obesity negatively affect the parameters of health-related fitness and interfere with the performance of certain motor tasks. These results suggest that it is necessary to influence the reduction of the prevalence of overweight and obesity, to promote and influence the increase of the level of physical activity in children in order to improve the parameters of health-related fitness from earliest childhood, and use it as a strategy in the fight against the prevalence of children obesity.

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UTICAJ MORFOLOŠKIH KARAKTERISTIKA NA PARAMETRE ZDRAVSTVENOG FITNESA PREKOMERNO UHRANJENIH I GOJAZNIH DEČAKA

Cilj rada bio je da se utvrdi uticaj morfoloških karakteristika na parametre zdravstvenog fitnesa prekomerno uhranjenih i gojaznih dečaka uzrasta osam godina. U istraživanju je učestvovalo 314 dečaka koji su pohađali drugi razred osnovnih škola na teritorijama gradova jugoistočne Srbije. Za procenu morfoloških karakteristika korišćeni su parametari longitudinalnih (3), transverzalnih, (3), cirkularnih dimenzija (3) i mase tela i mere potkožnog masnog tkiva (3). Parametri zdravstvenog fitnesa utvrđeni su pomoću testova za procenu mišićnog fitnesa, telesne kompozicije i kardiorespiratornog fitnessa. Za utvrđivanje uticaja morfoloških karakteristika na parametre zdravstvenog fitnesa korišćena je regresiona analiza. Rezultati istraživanja ukazuju da postoji statistički značajan uticaj (p=.000) morfoloških karakteristika na većinu parametara zdravstvenog fitnesa. Statistički značajan uticaj nije utvrđen kod testa pretklon-zaklon-izbačaj ∑ kod ispitivanog uzorka.

Ključne reči: *fitnes parametri, morfološke karakteristike, zdravstveni fitnes, kardiorespiratorni fitnes*

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Research article

EFFECT OF CORRECTIVE GYMNASTICS ON MUSCLE ASYMMETRY IN PRESCHOOL CHILDREN

UDC 796.012:615.82/.84-053.4

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Abstract. *The aim of the study is to determine the influence of developmental gymnastics intervention on muscle asymmetries along the spinal column in the sagittal plane in preschool children from Subotica. The sample consisted of 133 preschool children and was divided into three subsamples, the experimental group E1-45 (25.57%), the experimental group with additional exercise E2-45 (25.57%), and the control group K-86 (48.86%). A 10-week experimental exercise treatment was applied to two groups of participants, one of which had one additional exercise at home with their parents. Contemplas 3D Compact analysis was applied to assess muscle asymmetries (Professionalmotion analysis software) taking into account the variables related to the sagittal plane. By analyzing the results of the multivariate analysis of covariance it could be concluded that there are statistically significant differences (p = 0,03) between samples of different groups for the assessment of the parameters of the spinal column in the sagittal plane on the value of Pillai's Trace PT= 2,52 at the final measurement compared to the initial one. It can be pointed out that there are positive and visible effects of treatment on children from the experimental group, and that the program of corrective gymnastics has an impact on reducing muscle asymmetries in the sagittal plane, while the greatest effects are visible in the lumbar spine.*

Key words: *Corrective Gymnastics, Contemplas, Muscle Asymmetries*

1. INTRODUCTION

Physical activity is one of the most important methods of improving and enhancing children's health (Jin et al., 2018), while physical inactivity on the other hand negatively

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affects health homeostasis, primarily health, quality of life and social aspects of development (WHO, 2016). A high level of sedentary behavior is associated with short-term and long-term psychophysiological health consequences (Hinkley et al., 2014; Katzmarzyk et al., 2009). The *Canadian Society for Exercise Physiology, Department of Health, Physical Activity, Health Improvement and Protection and Department of Health and Aging, Australia* (2012) recommends that children during growth and development should be exposed to at least two or three hours of daily physical activity, and on the other hand, their time spent in a sedentary regime should be limited. Physical activity is very important for the undisturbed development of children (Strong et al., 2005), and accordingly it is assumed that muscle inactivity negatively affects the formation of asymmetries that can develop into more serious incorrect postures.

The physiological sagittal spinal curvature represents a typical feature of good posture in the sagittal plane. The pelvis leans forward, and the lower limb joints stay in neutral position which represents good body posture. Bad body posture can appear due to weak muscles and muscle asymmetry of the left and right, front, and back side of the body. Posture quantification is conducted by noticing minor displacements of the body's center of gravity or radiographic lateral asymmetries. (Thomkinson & Shaw, 2013, Schmid et al., 2015). Bad body posture assessment is conducted using digital photometry (Stolinski, et al., 2017) with Contemplas being one of the recognized methods. This method has been implemented on older and younger school children (Kojic, 2014; Kovac et al, 2015; Scepanović, 2017, Kapo et al, 2018).

There are various reasons for the occurrence of postural disorders in children and young people, but they most often appear in the form of idiopathic disturbed postures (Eider & Paczyńska-Jędrycka, 2014). During the preschool age and even school age, the child's posture is formed by many external influences, which lead to inadequate postural habits. Impaired posture, among other things, can occur as a consequence of reduced range of motion, i.e. all those factors that define the hypokinetic syndrome. On the other hand, good postural status, i.e. proper posture, can be defined as a state of good musculoskeletal balance that protects against the emergence and progressive development of postural disorders (Madic, 2014). However, the lack of muscle activation, logically, implies muscle weakness due to which muscle imbalances can also occur (Nosko et al., 2016). If, for example, we consider the positions of the scapular or shoulder region, the consequences may be muscle atrophy, disturbed bone contour, a lower scapular angle due to muscle inactivity, weakness and lack of strength of the rotator cuff muscles (Burkhart et al., 2003; Kibler, 2003; Kibler et al. , 2002, Meister, 2000). Prolonged sitting leads to changes in postural status, changes in the position of the head, thoracic and lumbar spine (Clausi et al., 2016), with the forward head posture. Bad life habits have a negative impact on muscle integrity, both on the length of the muscle itself (usually muscle shortening and reduced elasticity) and muscle efficiency (reduction of muscle function). One of the most effective ways to prevent the development of impaired posture is prevention – i.e. the educational process (Kutis et al., 2017), parental involvement, both in the prevention and correction of impaired posture (Mrozkowiak et al., 2016), as an adapted and properly dosed physical activity (Feng et al, 2018, Wyszyńska et al., 2016). Incidence of muscle asymmetries, i.e. disturbed postures, has been constantly increasing in recent years, and their higher frequency is reported due to the improvement of diagnostic procedures in the child population, and the use of modern detection methods and software (Kutis, 2017). Therefore, there is a need for constant screening and development of new training forms that would have an impact on prevention and correction when it comes to muscle asymmetries or impaired posture. Certain knowledge in this field can contribute to a more adequate and thorough approach in the treatment of disturbed postures.

Based on the presented facts, the research objective is set, which includes determining the efficiency of the kinesitherapy program, i.e. corrective gymnastics, with additional exercise for muscle imbalances to be performed with the parents.

2. METHOD

2.1. Participants

This is a longitudinal-type study which involved the application of a ten-week developmental gymnastics intervention on children aged 5 to 7. The total sample of children (n=133, Fig. 1) was divided into three sub-samples: experimental group E1 - 45 (25.57%), experimental group with additional exercises E2 - 45 (25.57%), and the control group C-43 (48.86%). The average age of the total sample was 6.19±0.58 years, and the participants were classified into groups by approximately the same age (p=0.83). The average age of the participants in the control group was 6.18 ±0.60, the average age in the experimental group with the intervention 6.21±0.57, and the average age of the participants in the experimental group with the intervention and additional exercises at home was 6.19±0.57 years. Two experimental interventions were implemented in groups E1 and E2. There were only 43 participants in the control group due to a smallpox epidemic in the preschool.

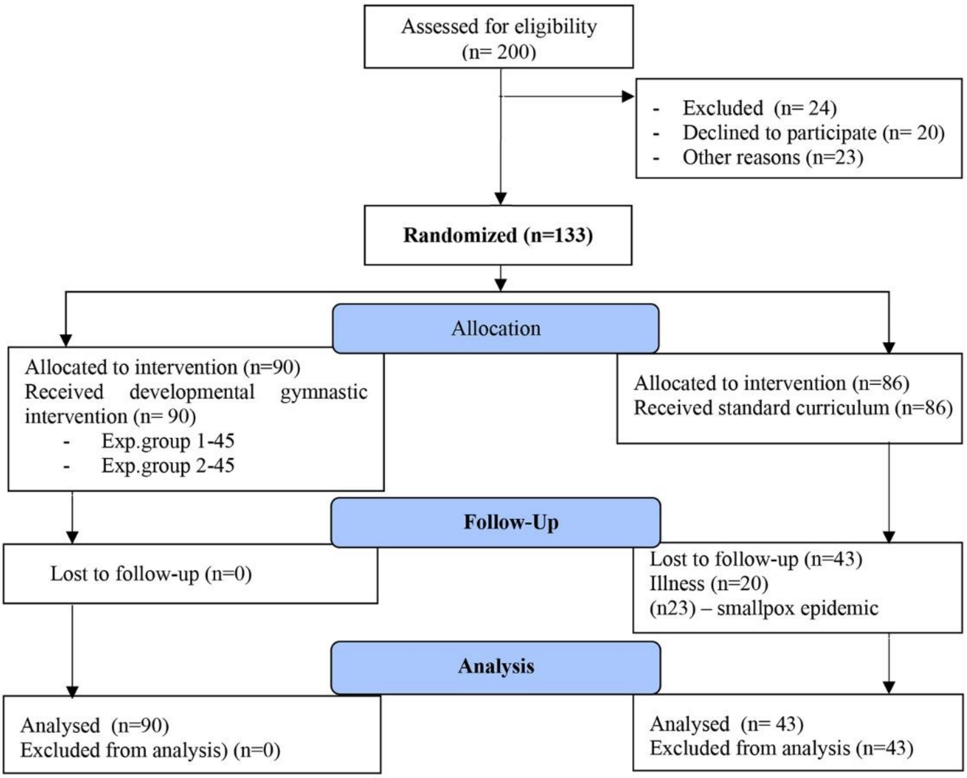

Fig. 1 CONSORT flow diagram

2.2. Procedures/testing

3D Compact analysis by Contemplas (*Professional motion analysis software*) was applied for assessing muscle asymmetries – the photometrics method. The results are obtained in the form of simple animations that give a precise picture of muscle deviations, i.e. the asymmetry of the body. Recording is done with three cameras, after which reports are received. Marking of reference points enables reading of the position of the shoulders, pelvis, body posture in the sagittal and frontal plane, as well as the position of the legs. The 3D module consists of three cameras on the basis of which a precise image of the postural status is obtained from all three perspectives, and the accuracy of the system was confirmed by the Cologne University of Sports (Scepanovic et al., 2015). The variable sample consists of 3 variables acquired by "3D posture compact" testing protocol (Table 1).

Table 1 Variables and abbreviations for 3D posture analysis

Sag. Distance cervical spine – sacrum	The variable is expressed in centimeters and indicates the distance between the most protruded cervical (neck) vertebra and the projected vertical line of the sacrum (the bone at the bottom of the spine) in the sagittal plane. A positive result means a more pronounced flexion of the cervical spine, while a negative result means a more pronounced extension of the cervical spine.
Sag. Distance thoracic spine – sacrum	The variable is expressed in centimeters and indicates the distance between the thoracic spine and the projected vertical line of the sacrum (the bone at the bottom of the spine) in the sagittal plane. Positive results indicate a more pronounced flexion in the thoracic spine, while negative results indicate a more pronounced other extension of the thoracic spine.*Higher positive and negative offsets do not apply to the variables.
Sag. Distance lumbar spine – sacrum	The variable is expressed in centimeters and indicates the distance between the lumbar (lower) spine and the projected vertical line of the sacrum (the bone at the bottom of the spine) in the sagittal plane. A positive result means a more pronounced lumbar spine flexion, while negative results means a more pronounced lumbar spine extension.

2.3. Testing protocol

The test protocol first involves placing the Contemplas flat panel (Figure 2). In order to place it correctly, it is first necessary to find an ideally flat surface. It is necessary to fix the Contemplas panel to the substrate so that it does not move during the screening itself. After forming a flat surface, it is necessary to form a calibration 3d frame or a frame that contains reflex markers (Figure 3).

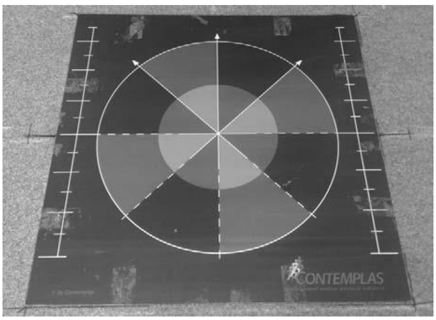

Fig. 2 Screening surface

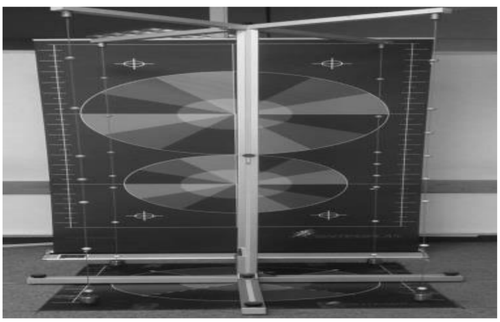

Fig. 3 Calibration frame

The complete calibration space consists of the Contemplas panel ideally aligned with the calibration frame (Figure 4). The relationship between these two segments must be ideally aligned, which is checked by using a spirit level. After the formation of the calibration space, 3 cameras are installed that enable three-dimensional analysis.

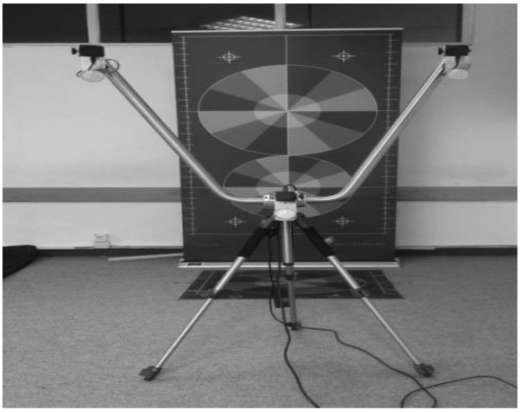

Fig. 4 V Camera Frame

The distance of the camera from the screening surface should be at least two meters. The screening process begins by checking the image quality on the software and after that the camera starts calibrating the space. The next step involves marking the participant at precisely defined specific points on the body (Figure 5).

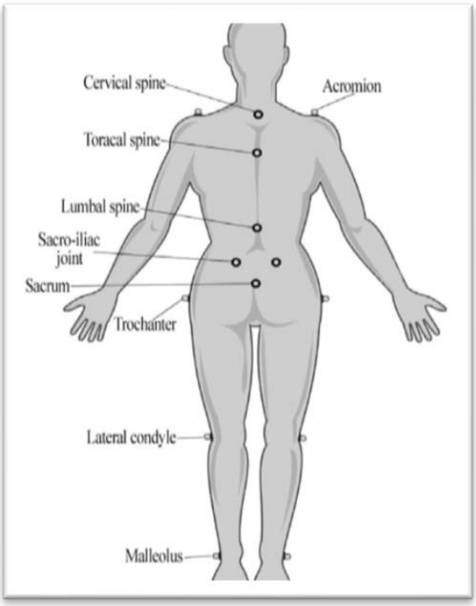

Fig. 5 Positions of the markers of the “3D Posture Compact” protocol

2.4. Training program

The E1 module included a 10-week experimental intervention and included two individual 45-minute interventions weekly managed by the author of this study. The intervention included the developmental gymnastics treatment designed to treat primarily the antigravity muscles, but also motor coordination and postural stability. The E2 module included a separate part of the intervention which was implemented by the children's parents at home, and added to the Module 1 settings. The additional 20-minute intervention was realized at home, two times a week. The parents were previously trained and provided with an exercise plan which they followed during the intervention, and recorded it on a regular basis in a log prepared by the author. The goal of the intervention was to equally strengthen the back muscles including the lower back muscles and the shoulder and scapula muscles. The intervention was not applied to the control group. During the intervention, the E1 group performed 20 individual exercise units (module 1), whereas the E2 group performed 20 exercise units from Module 1 and 20 additional exercise units of Module 2. All the exercises were designed to lead to a positive transfer and, since the children are of the preschool age, the classes were divided into the following four parts: introductory, basic, main, and final section. Each part was envisaged according to the plan and as a continuation of the previous class.

2.5. Intervention programs

The E1 module (Table 2) implied an experimental intervention lasting ten weeks and included two individual interventions of 45 minutes during a week which were managed by the author of this paper. The intervention implied the application of developmental gymnastics contents designed to treat primarily the antigravity muscles, motor coordination and postural stability as well (Table 2). We used the Borg rate of perceived exertion (RPE) scale (1–10) and asked each participant to provide their overall RPE for the session. It was shown previously that children, even as young as 5–6 years of age, can become quite adept at rating their perceived exertion. The E1 program was organized in the form of frontal, group work but mostly as circuit training (polygon) or repetitive (station) training. If the exercise was performed within the polygon, the children were to do the task and move to the next station. Obstacles consisted of various gymnastic apparatus and props for solving motor problems made up of gymnastic and athletic exercises, as well as elementary games. Station training was made up of repeating the same exercises more than once on one station (e.g., one gymnastic apparatus). In this case, the exercise was repeated. In order to increase the intensity of the exercises and reduce the waiting for the apparatus for exercise, some exercises with additional and complementary tasks were added (e.g., exercises for strengthening and stretching, as well as exercises on supplementary apparatus).

Table 2 E1 module: The structured exercise program

Duration	Organization	Volume	Frequency	Intensity
10 weeks	Frontal work, group work, group with stations, polygon and circuit work	45 minutes per session	2 times a week	According to external signs (sweat, flush, spontaneous break

The training structure: a 10-minute warm-up consisted of various natural forms through play which aimed at raising the children's functional capacities. The 30-minute main part was conducted through exercises aimed at the development of motor abilities, anthropometric and morphological elements strengthening the muscle system. The 5-minute cool-down part was comprised of a combination of stretching exercises on Swedish ladders, fitness balls, and mats.

The E2 module (Table 3) was designed to include a separate part of the intervention implemented by the children's parents at home, in addition to Module 1. The additional intervention was realized at home, for 20 minutes twice a week (Table 3) The previously trained parents were provided with the curriculum they followed during the intervention and regularly recorded it in a log given by the author. The intervention was aimed at strengthening the muscles of the back including the lower back muscles and the muscles of the shoulder and scapula region equally represented.

Table 3 E2 module: The structured exercise program

Duration	Organization	Volume	Frequency	Intensity
10 weeks	Individual work,	20 minutes per session	2 times a week	According to external signs (sweat, flush, spontaneous break

The control group was not part of the treatment in the preschool and only had non-structured physical activity and play in their free time.

2.6. Statistical analysis

The statistical software SPSS Statistics for Windows, version 20 was used for statistical data processing. All collected data were processed by descriptive and comparative statistics procedures. The statistical method of data processing determined the basic descriptive statistics of variables: arithmetic means (AM), standard deviation (S), coefficient of variation (CV) of the initial and final screening, separately for all three groups of participants. The normality of the distribution was checked using the Shapiro-Wilk test for small samples at the significance level of $p \leq 0.05$. Multivariate analysis of variance (MANOVA) was used to determine differences in the entire posture space at the initial and final measurements, and One-Way ANOVA was used to determine individual differences. The effects of the treatment were determined by multivariate analysis of covariance (MANCOVA) and univariate analysis of covariance (ANCOVA). After determining significant differences between the groups of participants using the Bonferroni comparison, an attempt was made to determine between which groups real differences could be found. Due to an uneven number of participants, Pillai's Trace statistic was used.

3. Results

3.1. Descriptive statistics of variables analyzed in initial screening depending on the group

Descriptive statistics of variables of the spinal column in the sagittal plane at the initial screening in all three analyzed groups (Table 4) indicate exceptional heterogeneity of the results with significant individual differences. The parameters of the spinal column in all three groups have a normal distribution.

Table 4 Descriptive statistics of variables of the spinal column in the sagittal plane at the initial screening of different groups

Variable	Control (N=37)			Experimental 1 (N=22)			Experimental 2 N=41		
	AM±S	CV	SWp	AM±S	CV	SWp	AM±S	CV	SWp
Cervical lordosis (cm)	0.84±3.01	27.91	0.51	0.89±2.03	43.84	0.43	1.69±2.91	58.08	0.60
Thoracic kyphosis (cm)	-2.12±3.09	68.61	0.59	-1.41±1.54	91.55	0.58	-1.12±3.26	34.36	0.11
Lumbar lordosis (cm)	0.36±2.20	16.36	0.46	1.35±1.95	69.23	0.61	0.92±1.83	50.27	0.67

Legend: C - control group, E1 - experimental group with treatment; E2 - experimental group with treatment and additional exercise at home; AM - arithmetic mean; S - standard deviation; CV - coefficient of variation; SWp - level of statistical significance of Shapiro Wilk coefficient

Descriptive statistics of variables of the spinal column in the sagittal plane at the final screening (Table 5) in all three analyzed groups indicate exceptional heterogeneity of the results with significant individual differences. In all other analyzed variables, a normal distribution of the results is observed.

Table 5 Descriptive statistics of the variables of the spinal column in the sagittal plane at the final screening of different groups

Variable	Control (N=37)			Experimental 1 (N=22)			Experimental 2 N=41		
	AM±S	CV	SWp	AM±S	CV	SWp	AM±S	CV	SWp
Cervical lordosis (cm)	0.81±2.91	27.84	0.08	0.57±2.46	23.17	0.29	0.76±1.71	44.44	0.40
Thoracic kyphosis (cm)	-2.06±2.38	86.55	0.13	-1.96±1.94	101.03	0.71	-1.25±1.54	81.17	0.52
Lumbar lordosis (cm)	1.65±2.02	81.68	0.48	1.90±2.79	68.10	0.54	1.05±0.91	115.38	0.78

Legend: C - control group, E1 - experimental group with treatment; E2 - experimental group with treatment and additional exercise at home; AM - arithmetic mean; S - standard deviation; CV - coefficient of variation; SWp - level of statistical significance of Shapiro Wilk coefficient

3.2. Differences between groups at initial screening

By analyzing the results of multivariate analysis of variance (Table 6), it can be concluded that there are no statistically significant differences (p=0.38) between the participants from the experimental groups and control group in the variables used for assessment of the spinal column in the sagittal plane with a PT test value of 1.08. Prior to the application of the treatment, no statistically significant differences were found between the groups in the parameters of the spinal column in the sagittal plane.

Table 6 Differences between participants from different groups in the parameters of the spine in the sagittal plane - initial screening

Variable	f	P	PT	P
Cervical lordosis	1.09	0.34		
Thoracic kyphosis	1.20	0.31	1.08	0.38
Lumbar lordosis	1.80	0.17		

Legend: f - univariate f test; p - level of statistical significance of the f test; PT - multivariate Pillai's Trace test; p - statistical significance of multivariate PT test

3.3. Differences between groups at the final screening

By analyzing the results of multivariate analysis of variance (Table 7), it can be concluded that there are no statistically significant differences (p=0.07) between the experimental groups and control group in the variables used for assessment of the spinal column in the sagittal plane at PT test value 1.98 at the final screening. No statistically significant differences were found in the entire region of the spinal column, but also no individual differences.

Table 7 Differences between subjects from different groups in the parameters of the spine in the sagittal plane - the final screening

Variable	f	p	PT	P
Cervical lordosis	0.05	0.95		
Thoracic kyphosis	1.59	0.21	1.98	0.07
Lumbar lordosis	1.47	0.24		

Legend: f - univariate f test; p - level of statistical significance of the f test; PT - multivariate Pillai's Trace test; p - statistical significance of multivariate PT test

3.4. Effects of treatment on parameters of the spinal column in the sagittal plane

By analyzing the results of the multivariate analysis of covariance (Table 8), it can be concluded that there are statistically significant differences (P=0.03) between the participants from the experimental groups and control group in the variables for estimating the parameters of the spine in the sagittal plane.

By equalizing the participants before the application of treatment and by individual observations, it can be concluded that these differences were found to the statistically significant extent only in the variable *Lumbar lordosis* (p=0.02) (Table 8).

Table 8 Multivariate analysis of covariance for the analyzed variables (MANCOVA)

Factor	Variable	f	p	Group	AM*	PT	P
Group	Cervical lordosis	0.10	0.90	C	0.75	**2.48**	**.03**
				E1	1.13		
				E2	0.76		
	Thoracic kyphosis	1.96	0.15	C	-2.18		
				E1	-1.19		
				E2	-1.25		
	Lumbar lordosis	**3.96**	**0.02**	C	1.58		
				E1	2.68		
				E2	0.98		

Legend: E1 - experimental group with treatment, E2 - experimental group with treatment and additional exercise at home, C - control group; f - univariate f test; p - level of statistical significance of the f test; PT - Pillai's Trace test; p - statistical significance of multivariate PT test; AM* - adjusted arithmetic mean

In order to determine the real differences between the groups, the Bonferroni comparison (Table 9) was applied on a more sensitive criterion ($p \leq 0.0167$). The Bonferroni comparison was applied to determine the real differences between the groups. Based on it, it is concluded that there are no statistically significant differences between groups on the more sensitive criterion ($p \leq .0167$), but that the treatment gave positive effects, because lower average values of the analyzed variable in the lower part of the spinal column in the sagittal plane were observed. The largest differences in arithmetic means were found between the experimental group (E1) and the experimental group that exercised additionally at home (E2) in favor of the experimental group E2.

Table 9 Real differences between groups

Dependent Variable	(I) Group	(J) Group	AM difference (IJ)	p
Lumbar lordosis final	E1	C	1.10	0.253
		E2	1.70	0.024
	C	E2	.59	0.621

Legend: E1 - experimental group with treatment, E2 - experimental group with treatment and additional exercise at home, C - control group; p - level of statistical significance

4. Discussion

The critical time point for the occurrence of muscle asymmetries, and even spinal deformities, in the period of growth and development of a child, is the juvenile period from 4 to 7 years of age, which can be marked as the time period when it is necessary to pay special attention to possible muscle asymmetries. The aim of the study was to determine the effectiveness of the training content, which was composed of elements of developmental gymnastics (E1 module), as well as elements of standard kinesitherapy exercises that treat the muscles of the spine (E2 module). The research was conducted on a sample of preschool children.

The analysis of the obtained results shows that the postural status of the spinal column in the observed sample of participants before treatment was disturbed, especially the thoracic segment of the spinal column. The initial screening did not show statistically significant differences in the postural status of the spine in the sagittal plane, but there was a significant negative trend in favor of increasing the curvature of thoracic kyphosis and lumbar lordosis to the extent that it deviates from normal physiological values. The results can be explained by the fact that the level of physical activity of children is reduced already in the preschool age, which can contribute to a greater occurrence of postural poor posture and muscle asymmetries. This confirmed the results of the research of Koroljev et al. (2015) who, with the help of the same research method, determined the existence of postural deviations in the sagittal plane on a similar sample of participants, with asymmetries (changes) in the thoracic spine also predominating. The described values of results in variable *Thoracic kyphosis* at the initial screening are quite similar to the results of research by Koroljev et al. (2015). The greatest similarity of results is observed in the experimental group with treatment (E1), because in the study of Koroljev et al. (2015), the average value of thoracic kyphosis was -1.40 cm, and in the mentioned group -1.41 cm. Compared to the results of the control group, the results were on average worse in relation to the mentioned research (even on average worse by 1.51 cm). The experimental group with treatment (E2) recorded on average better (lower) values in the thoracic spine of -1.12 cm in relation to the stated results of the research of Koroljev et al. Results for the variable *Cervical lordosis* were quite similar to the results of Koroljev et al. (2015), except in comparison with the experimental group that also exercised at home, which had much greater asymmetries in this segment of the spine (1.69 cm compared to 0.95 cm). For the variable *Lumbar lordosis*, comparing the results with the results of the research of Koroljev et al (2015), better average results in the control and experimental group with treatment (E2) were observed (1.17 cm on average observed in the mentioned study), and worse average results in the group with treatment only (E1). The above research results before treatment (initial state) and the position of the marked points of the spine in the sagittal plane indicate certain muscle asymmetries that already in the preschool period take the form of an increase in cervical lordosis, thoracic kyphosis, and lumbar lordosis.

The results of the current study indicated the fact that there are statistically significant differences between the participants from the experimental groups and control group in the variables for assessing the parameters of the spine in the sagittal plane with the greatest effects in the lumbar region, with visible positive effects of treatment on the experimental group of children who exercised at home. Experimental group 1 did not make progress in all three spinal column variables because they were not under the kinesiotherapy treatment, but instead conducted the development gymnastics program, while E2 had the development gymnastics treatment together with specific kinesiotherapy exercises which engaged the spinal column muscles and activated the lumbar spinal part with every move more and cervical and thoracic part less. E2 still made more progress than E1 in the cervical spinal part (E2 initially 1.69 to 0,76 finally), although with no statistically significant difference. Comparison of the results from this research with the results for participants of a similar age obtained by a group of authors Scapanovic, Marinkovic, Korovljev and Madic (2015) where the sample was composed of 416 female participants, 7.68 years old on average, shows significantly lower average values in children from Subotica in two of the three analyzed variables of the spine in the sagittal plane. These are cervical and lumbar lordosis, where on average lower values were recorded than in the mentioned research, in two or three groups of participants. In the research by Scepanovic et al (2015), the average value was 1.83 cm for the variable *Cervical lordosis*, which is much higher than in the control group (0.84 cm), the experimental group with treatment (0.89 cm), and the experimental group with treatment and additional exercise at home (E2) where the average value at the initial screening was 1.65 cm. Lower average values with the same sign in the variable *Lumbar lordosis* were also found. The increase in the curvature of the spinal column can be explained by the fact that the participants in the research by Scepanović et al. (2015) were on average older and that the neck and lumbar curvature increased with age and the thoracic curvature of the spine decreased. Such results can be justified only by the age of the children, because the participants from Subotica were almost a year younger. An increase in cervical and lumbar lordosis has been confirmed in previous studies on a similar sample of participants (Protic-Gava et al., 2009). The decrease in chest curvature can be explained by the displacement of the center of gravity of the body forward, which is a consequence of the shifted position of the head. Recent clinical research shows a noticeable shift of the head forward, and thus the entire upper part of the body shifts forward. The pelvis leans forward, which implies an increase in lumbar curvature, which creates compensation, and at the same time an equilibrium position.

Contrary to the results of Scepanović, Marinkovic, Madic and Protic-Gava (2017), where the developmental gymnastics treatment of the muscle asymmetry and correction of poor posture lasted 12 weeks and no statistically significant improvements were observed, the results of this study showed that a 10-week treatment in a home setting can still lead to improvement in the condition of the lower back muscles. The changes were positive, but the greatest effects were achieved in the lumbar segment of the spine. Obviously, the parents, with their influence, managed to motivate the children to actively exercise, as recommended by experts. Accordingly, it can be stated that the experimental treatment contributed to the reduction of muscle asymmetries in the lumbar region, i.e. caused some corrections in the form of reduction of deviations in the specified region of the spine in the sagittal plane in the experimental group under additional treatment, i.e. exercise at home. It is well known that lumbar lordosis is most often corrected by changing the position of the pelvis in the sagittal plane, so the achieved changes are the result of good pelvic positioning during exercise, and at the same time strengthening the deep abdominal muscles and back muscles, thus achieving muscle recalibration. By activating and strengthening the deep muscles of the abdomen and the lumbar region of the back, the activation of the superficial muscles, which is directly responsible for creating an excessive lumbar lordotic curve, is reciprocally reduced. Suboptimal activation of the diaphragm, pelvic floor, transverse abdominal muscle, as well as oblique abdominal muscles, will lead to excessive activation of superficial muscles of a given region, which will try to compensate for deep muscle inactivity and stabilize the lumbar spine. As the superficial muscles are longer, and thus cross over more segments of the spine or even other bones (e.g. *m. Iliopsoas*), their stabilization and reduced activation led to a change in the statics of the lumbar spine and pelvis, and thus increased lumbar lordosis.

Inability of posture to adequately resist either internal or external forces is described by a prevalence of up to 65% (Gh Maghsoud et al., 2012; Kratěnová et al., 2007; Wirth et al., 2012). According to such indicators, it is assumed that the weakened muscles are more susceptible to the acute effects of a ten-week treatment, and that the effects of the treatment were more pronounced due to more regular muscle toning that takes place under the control of the parents. There is also the fact that the participants from the control group and the experimental group that exercised in kindergarten may have had insufficient physical activity during the day which can lead to an increase in lumbar and other curvatures of the spine in this period of life (Ho Ting Yip, Tai Wing Chiu and Tung Kuen Poon, 2008).

The absence of results in the cervical and thoracic spine can be attributed to the insufficient specificity of the exercises for this region, since the musculature of the ventral side of the neck is not significantly affected by these exercises. Upright posture, i.e. centering of the cervical spine, is possible only if there is activation of its ventral aspect, i.e. *m. longus colli* and *m. longus capitis* as an addition to dorsal musculature activation (Kolar, 2006). On the other hand, the presence of positive results in the lumbar region can be attributed to the continuous activation and strengthening of the core muscles, which has a direct impact on the stabilization of the spine (Kibler et al., 2006). The reduction in lumbar lordosis due to the activation of the core muscles is most likely a consequence of the creation of intra-abdominal pressure, which occurs when all the core muscles are activated at the same time. Coactivation of the diaphragm, pelvic floor and abdominal muscles creates intra-abdominal pressure. Negative pressure in the abdomen does not allow translational movement of the spine forward and thus prevents excessive lordotic position of the lumbar spine. The interaction between the IAP and the spinal extensor fixes the spinal column and the pelvis. In physiological conditions, where there is such an interaction, the joints of the lumbar spine are in a centered position during the activation of the muscles of the upper and lower extremities, which means that when activating the muscles of the extremities, there will be no movement and decentration between the lumbar vertebrae, and thus there will be no excessive lumbar lordosis.

The fact that there are no statistically significant differences between group E2 and group C that was not treated indicates that versatile physical activity also has a very significant impact on postural status. If we look at muscle imbalance through the neurological paradigm (Paige, 2009), i.e. that muscle imbalance is a consequence of reduced movement, as well as reduced diversity of movement, it is clear that even nonspecific exercise, which includes standard activities such as jumping, running, prolonged squatting, has an impact on a harmonious and balanced muscular, and thus skeletal system. The control group performed standard activities that were not programmed to treat specific musculature, which again indicates the fact that versatile physical activity can also have an impact on a harmonious and balanced muscular system (Karaleic et al., 2014). There was no deterioration of the results compared to the initial state, which leads to the conclusion that positive effects of exercise were observed in all three groups of participants. But it should be noted that better results are achieved by targeted action and treatment on target regions and body parts in preschool children, mostly on the lumbar spine.

5. Conclusion

The effects of the treatment can be characterized as positive and successful on a sample of preschool participants. The very fact that there was an improvement in the position of lumbar lordosis and thus an improvement in sagittal balance shows us that the treatment had a significant effect on children who exercised additionally at home. The application of 3d analysis proved to be very demanding on a population of preschool children. Namely, even the smallest muscle contraction or change of position of a body segment at the moment of imaging in the 3d protocol analysis can have an impact on the obtained results, and must be approached thoroughly and very precisely. The recommendation for further research would be to consider the effects of developmental gymnastics on the sagittal plane as well.

The obtained research results expand the theoretical picture of the application and frequency of exercise in preschool children and its impact on muscle imbalances and asymmetry. From a practical point of view, it is possible to implement the results of this work in a regular preschool program. The realization of this research contributes to the scientific community as a basis for further research, the possibility of comparing data and expanding scientific material. This paper could also contribute to anthropological disciplines such as kinesitherapy, biomechanics, by analysis of the state of certain anthropological dimensions of children with more pronounced asymmetries in the sagittal plane.

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EFEKAT KOREKTIVNE GIMNASTIKE NA MIŠIĆNE ASIMETRIJE KOD DECE PREDŠKOLSKOG UZRASTA

Cilj studije je da se utvrdi uticaj korektivne gimnastike na mišićne asimetrije na nivou kičmenog stuba u sagitalnoj ravni kod dece predškolskog uzrasta iz Subotice. Uzorak je činio 133 dece predškolskog uzrasta i bio je podeljen na tri subuzorka, eksperimentalnu grupu E1-45 (25.57%), experimentalnu grupu sa dodatnim vežbanjem E2-45 (25.57%) i kontrolnu grupu K-43 (48.86%). Primenjen je eksperimentalni tretmana vežbanja u trajanju od 10 nedelja na dve grupe ispitanika, od kojih je jedna imala i još jedno dodatno vežbanje kod kuće sa roditeljima. Za procenu mišićnih asimetrija primenjena je 3D Compact analiza marke Contemplas (Professional motion analysis software) gde su uzete u obzir varijable koje se odnose na sagitalnu ravan. Analizom rezultata multivarijatne analize kovarijanse može se zaključiti da postoje statistički značajne razlike (p=0.03) između ispitanika eksperimentalnih i kontrolne grupe u varijablama za procenu parametara kičmenog stuba u sagitalnoj ravni pri vrednosti Pilar' s Trace koeficijenta PT=2.52. Može se istači da postoje pozitivni i vidljivi efekti tretmana na eksperimentalnoj grupi dece i da je program korektivne gimnastike uticaj na smanjenje mišićnih asimetrija i sagitalnoj ravni, a najveći efekti su vidljivi u lumbalnom delu kičmenog stuba.

Ključne reči: *korektivna gimnastika, contemplas, mišićne asimetrije*

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Research article

POWER CHARACTERISTICS IN SENIOR BASKETBALL PLAYERS - COMPETITIVE-LEVEL DIFFERENCES

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Abstract. *The explosive power of the lower limbs is considered to be one of the most dominant factors in modern basketball. Based on that, we assumed that power characteristics are the factor that distinguishes basketball players of different quality levels. To set qualitative levels, we tested three teams of basketball players (a total of 39 players), each participating in a competition at a different rank, from the highest national (Elite), through second national (sub-elite) to the regional (Amateur) level. Each player completed three parts of testing: jumping tests, sprint tests and isoinertial power tests. Despite the obviously better results of the elite group in the sprint variables compared to the other two groups, statistically significant differences were observed only in tests in which maximal speed (10mF and 20m) was achieved (Elite vs. Amateur, $p<0.05$). In three jumping tests (SJ, CMJa and RJ) we obtained significantly better results in Elite players compared to the other groups (SJ: $p<0.01$; CMJa: Elite vs. Sub-elite $p<0.05$, Elite vs. Amateur $p<0.01$; RJ: $p<0.01$), while in CMJ only a difference between the Elite and Amateur group was observed ($p<0.05$). In isoinertial power tests, the only difference was obtained for knee extensor muscles (Elite vs. Amateur $p<0.05$). In accordance with the results, it can be confirmed that power is a crucial factor in basketball performance and should be a key element in the selection of young basketball players.*

Key words: *Quality Level, Performance, Sprint, Jumps, Selection*

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INTRODUCTION

Basketball is an intermittent, high-intensity team sport with complex demands based on individual skills, tactics and strategies, psychological aspects, and physical fitness (Drinkwater, Pyne and McKenna, 2008; Trninic and Dizdar, 2000). Among other factors, fitness plays an essential role in individual and team performance (Bale, 1991, McInnes, Carlson, Jones and McKenna, 1995; Ostojic, Mazic and Dikic, 2006). The basketball game consists of four 10-minute quarters with a 2-minute break between periods and a 15-minute break at halftime. Besides that, there are a lot of game interruptions such as time outs or different violation of rules. As a result, less than 50% of the game is spent in live play. These frequent stoppages allow players to recover between bouts of activity, thus allowing generally the high-intensity of the game (Cormery, Marcil and Bouvard, 2008). In conclusion, the modern game is mainly anaerobic, characterized by polystructural movements, which means that actions during the competition can be realized with a number of motor skills and physical characteristics.

As one of the most complex competitive activities characterized by constantly changed situations, the hierarchy and general structure of abilities for competitive success is a very difficult process. As a result, individuals with different structural abilities and characteristics can be noticed among the best basketball players, which additionally complicate the formation of model characteristics of basketball players. On the other hand, explosive movements such as short sprints, abrupt stops, fast changes of direction, acceleration, different vertical jumps are a crucial part of the basketball game (Zwierko & Lesiakowski, 2007; Erčulj, Dežman, & Vučković, 2004). Converted to motor skills, the ability to produce strength, power, and speed significantly contribute to efficient movement in basketball (Ziv & Lidor, 2009; Abd Al Jabbar, 2015).

The explosive power of the lower limbs, in particular jumping ability, is considered to be a dominant factor in basketball performance (Hoffman, Epstein, Einbinder and Weinstein, 1999). Specifically, a high level of lower-limb explosive power is useful for powerful activities such as accelerations and winning jumps during the game (Hoffman, Epstein, Einbinder and Weinstein, 1999; Hoffman, Tenenbaum, Maresh and Kreamer, 1996). In male professional basketball, players perform approximately 40 jumps of different intensities and more than 100 short sprints (1–2 s) per game, which gives a total of about 150 explosive activities during a game. Additionally, vertical-jump height was related to playing time in elite collegiate basketball, which means that coaches give preference to players with a high level of explosive abilities (Hoffman, Tenenbaum, Maresh and Kreamer, 1996). This is of particular interest to a game outcome because most scoring attempts came from very fast game situations (McInnes, Carlson, Jones and McKenna, 1995).

Previous studies reported that only 5% of sprints performed by basketball players lasted more than 4 seconds, and therefore it seemed that the highest intensity sprints consisted of fast acceleration and deceleration without developing a full speed (Ziv, & Lidor, 2009). Players with well-developed speed characteristics are capable of executing the elements of the modern basketball technique and tactics more efficiently (Harley, Doust and Mills, 2008). Therefore, we can argue that speed should be an important factor in the selection of basketball players (Jakovljević, Karalejić, Ivanović, Štrumbelj and Erčulj, 2017).

Comparisons between players involved in different competitive levels can help identify key physical elements that characterize higher-level players (Le Gall, Carling, Williams and Reilly, 2010; Scanlan, Dascombe and Reaburn, 2011). Studies reported better aerobic and anaerobic physiological adjustment during high-intensity activity in high-level players, compared to lower-level players (Ben Abdelkrim, Chaouachi, Chamari, Chtara and Castagna, 2010; Vernillo, Silvestri and La Torre, 2012; Ferioli et al, 2018). On the other hand, there are conflicting results about strength characteristics and jumping ability in players in different competitive levels (Ben Abdelkrim, Chaouachi, Chamari, Chtara and Castagna, 2010; Ferioli et al, 2018, Koklu, Alemdaroglu, Kocak, Erol and Findikoglu, 2011; Metaxas, Koutlianos, Sendelides and Mandroukas, 2009). Furthermore, the explosive power of the knee extensors did not prove to be sensitive among the qualitative groups. Nevertheless, high-level players possess a better explosive power than lower level players, as shown by the significantly higher ratio of flight and contact time during rebound jumps. This finding suggests that lower-leg explosive power might be considered as a discriminative variable in basketball (Castagna, Chaouachi, Rampinini, Chamari and Impellizzeri, 2009). To our knowledge, not a single study has considered knee flexor explosive power as a variable of interest in basketball. Besides, there is a lack of studies based on isokinetic or isoinertial measurements of strength and power in basketball.

Based on the aforementioned, we concluded that there are conflicting results and conclusions about the physical characteristics of basketball high-level players. Based on previous research, we assumed that power characteristics are the factor that distinguishes basketball players of different competitive levels, and we set an aim to determine which power characteristics differentiate players at these levels.

METHODS

Participants

For this study, 39 basketball players were selected, and consecutively divided into three groups. The first group consisted of 10 players from the teams of the highest Serbian basketball rank (Elite group). The second group consisted of 13 players from the second-best Serbian basketball league (Sub-elite group). Finally, the third group consisted of 16 players from the third-best Serbian basketball league (Amateur group). Their age and anthropometric characteristics are presented in Table 1. None of the participants reported any medical problems or recent injuries. They were informed regarding the potential risks associated with the applied testing protocol. They were also instructed to avoid any unusual strenuous activities throughout the study. All participants gave written informed consent to the experiments, in accordance with the Declaration of Helsinki adopted in 1964 and revised in 2013, and approved by the Institutional Review Board.

Testing procedures

Body height was assessed with a standard Martin anthropometer. Body mass and body fat percentage were assessed using a bioelectric impedance method (In Body 720; USA).

The participants performed maximal 20 m sprint with 10m split time. Therefore, results of the 10m sprint (10m), 10m flying start (10mF), and 20m sprint (20m) were obtained for further analysis. The participants were instructed to start when they are ready and run as fast as possible. Timings were taken using a set of infrared light gates (PAT 02, Uno-Lux NS, Serbia).

Participants were tested on 5 types of vertical jumps. Regarding the squat jump (SJ), they were instructed to hold their hands on their hips and perform a maximum vertical jump from a static starting position where the knee joint angle was fixed at 90°. Concerning the countermovement jump without arm swing (CMJ), the participants were instructed to perform an unconstrained maximum vertical jump from a standing upright position that included the initial counter movement, while keeping their hands on their hips. The countermovement jump with arm swing (CMJa), was performed in the same manner as the CMJ, whereas a natural arm swing was allowed. Regarding the drop jump (DJ), participants were instructed to land from a 30cm box and rebound vertically as quickly as possible with maximal effort just after ground contact with the intent of achieving maximum height. The participants kept their hands on their hips throughout the whole movement to minimize hip extension. Finally, to perform repetitive jumps (RJ) without arm swing, the participants were required to jump as high as possible for 7 consecutive efforts without a pause between jumps, whereas average jump height was chosen as a variable of interest. All jumps were performed on the ergo jump sensor mat (PAT 02, Uno-Lux NS, Serbia), whereas maximal jump height was chosen as a variable of interest.

Bilateral leg extension (LegExt) and leg flexion (LegFlx) tests were performed on the specific machines in the gym to calculate maximal power in watts. Participants were first instructed to perform a leg extension as fast as possible from the knee angle of 110º up to the full extension. Similar to that, leg flexion was performed from the knee angle of 180º up to the full flexion as fast as possible. Length and time to complete both the extension and flexion were measured via linear encoder (FitroDyne, Fitronic, Slovakia) attached to the machines (Jennings, Viljoen, Durandt and Lambert, 2005). Based on the length and the mass of the lifted weight, force, velocity, and consecutively power was calculated in the concentric muscle regimen (Harris, Cronin,Taylor, Jidovtseff and Sheppard, 2010).

Experimental protocol

Each participant completed 3 sessions separated by 5 to 7 days of rest.

The first testing session included anthropometric measurements as well as a verbal explanation of the upcoming tests. In addition, the first session consisted of one repetition maximum (1RM) test, performed separately for bilateral leg extension and bilateral leg flexion. Furthermore, percentages of 1RM were used to determine loadings for the LegExt and LegFlx test.

The second testing session consisted of a sprint test (10m, 10mF, 20m) as the first test, as well as a jump test (SJ, CMJ, CMJa, DJ, and RJ) performed in randomized order except for the RJ (always performed as the final test). All tests were performed 3 times, where the first time was a trial attempt. Furthermore, the best out of two trials was taken for further analysis. Due to the size of the test group (a minimum of 8 players) with participants performing the test one after the other, fatigue was never an issue.

In the third session participants performed only the isoinertial tests. Six maximal contractions of both LegExt and LegFlx (12 maximal contractions in total) were performed. In particular, 2 trials were performed per 3 different loadings (80%, 60% and 40%) for the LegExt, as well as 2 trials per 3 loadings (80%, 60% and 40%) for LegFlx. For both the LegExt and LegFlx tests, maximal obtained power was used for further analysis (regardless of the loading). The rest period between the trials and loadings was 3 minutes.

Finally, note that both the second and third sessions were preceded by a standard warm-up procedure for basketball players (10 min of callisthenic and dynamic stretching).

Statistical analysis

Prior to all statistical tests, descriptive statistics were calculated as mean and standard deviation. Furthermore, the normality distribution of the data was confirmed by Kolmogorov-Smirnov test. In addition, data distribution normality was also verified by the visual inspection of histograms and QQ plots.

One-way ANOVA was applied to test the age and anthropometric differences among the three groups. To assess differences between the three groups in the sprint, jump, and isoinertial tests, one-way ANOVA was applied as well.

In addition, for all ANOVAs, a Bonferroni post-hoc test was performed. The alpha level was set at $p \leq 0.05$. All statistical tests were performed using Microsoft Office Excel 2007 (Microsoft Corporation, Redmond, WA, USA) and SPSS 20 (IBM, Armonk, NY, USA).

3. RESULTS

The participants' age and anthropometric characteristics are depicted in Table 1. No significant differences between the participants were observed regarding age, body height, body mass, and BMI. The only significant difference between the groups was observed in Body fat percentage, where Elite players had a lower body mass percentage than the Amateurs.

Table 1 The participants' age and anthropometric characteristics presented as mean ± standard deviation.

Variables	Elite (n=10)	Sub-elite (n=13)	Amateur (n=16)
Age	22.9 ± 3.1	23.7 ± 3.0	23.2 ± 3.0
Body height (cm)	201.1 ± 6.4	196.1 ± 8.4	196.7 ± 8.5
Body mass (kg)	97.0 ± 12.5	92.6 ± 9.0	95.1 ± 14.0
BMI (kg/m^2)	23.9 ± 2.2	24.0 ± 1.2	24.5 ± 2.4
Body fat (%)	8.8 ± 1.2	11.4 ± 3.6	14.0 ± 5.5*

n = number of participants; BMI = body mass index; * significantly higher from Elite group at $p < 0.05$.

Regarding the sprint test (Figure 1), the one-way ANOVA performed on 10m did not show a significant main effect (F=2.823; p=0.073). On the other hand, significant main effects were observed when a one-way ANOVA was performed on 10mF (F=4.353; p=0.020) as well as 20m (F=4.004; p=0.027). In particular, the Elite players ran faster than the Amateurs in both the 10mF (p = 0.017) and 20m sprint (p = 0.024).

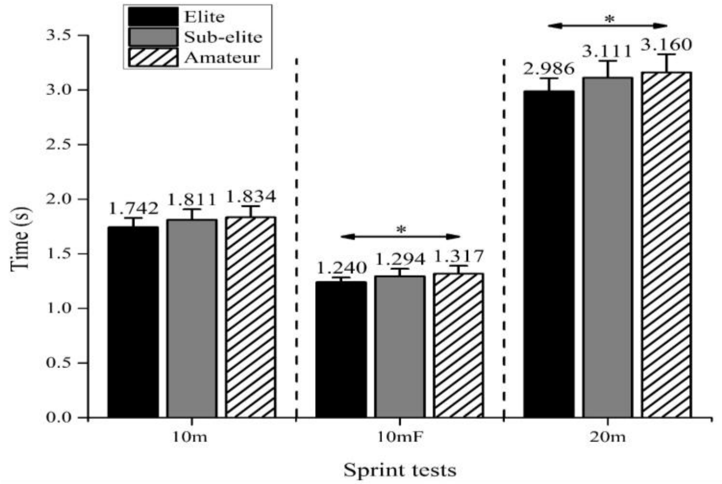

Fig. 1 Results from three participant groups obtained for the sprint test. Data showed as mean ± standard deviation. * - Significant differences at $p < 0.05$.

When the one-way ANOVA was performed on the jump tests (Figure 2), significant main effects were found for SJ (F= 11.849; p< 0.001), CMJ (F= 4.890; p= 0.013), and CMJa (F= 9.289; p= 0.001). Furthermore, Bonferroni post-hoc test results were depicted in Figure 2. Regarding SJ, Elite players jumped higher than both Sub-elite (p = 0.009), and Amateur players (p < 0.001). In the CMJ, Elite players only jumped higher than Amateur players (p = 0.011). Finally, regarding CMJ, Elite players jumped higher than both Sub-elite (p = 0.039) and Amateur players (p < 0.001).

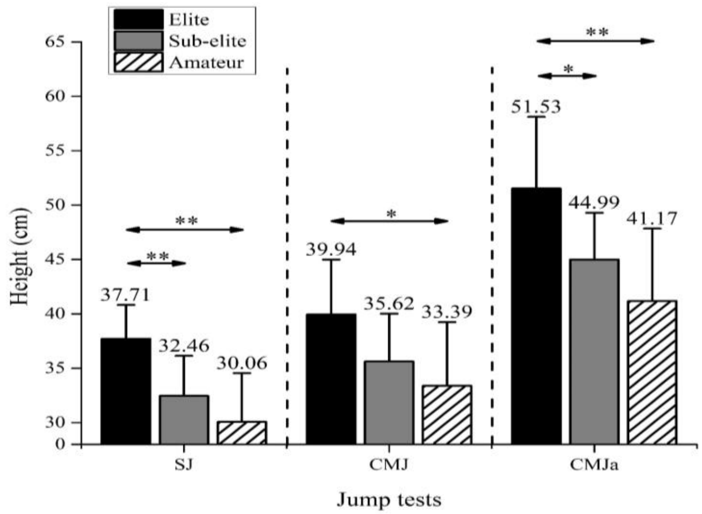

Fig. 2 Results from three participant groups obtained for the three jump tests. Data showed as mean ± standard deviation. * - Significant differences at $p < 0.05$. ** - Significant differences at $p < 0.01$.

Results of the DJ and RJ are depicted in Figure 3. Regarding the DJ, the one-way ANOVA did not show a significant main effect (F= 2.969; p= 0.064). On the other hand, a significant main effect was observed when one-way ANOVA was performed on the RJ (F= 8.82; p= 0.001). Regarding the RJ, Elite players jumped higher than both Sub-elite (p = 0.001) and Amateur players (p < 0.007).

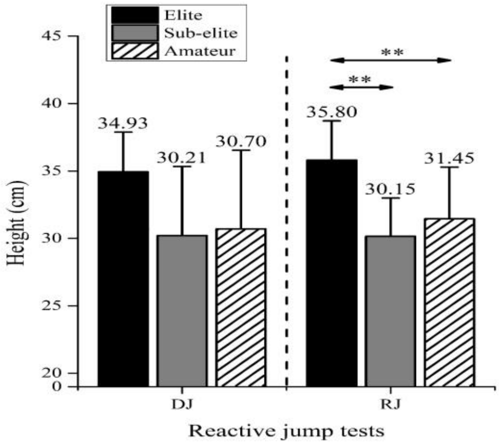

Fig. 3 Results from three participant groups obtained for the two jump tests. Data showed as mean ± standard deviation. ** - Significant differences at p < 0.01.

Finally, the results of the LegExt and LegFlx are depicted in Figure 4. Regarding the LegExt, the one-way ANOVA showed a significant main effect (F= 5.713; p= 0.007). In particular, Elite players achieved greater power than Amateur players (p = 0.005). On the other hand, the one-way ANOVA did not show a significant main effect for LegFlx (F=1.937; p=0.159).

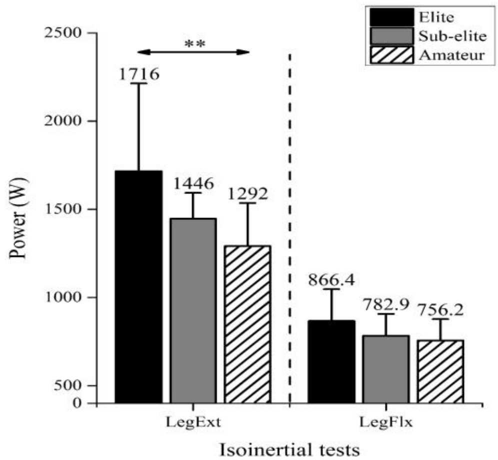

Fig. 4 Results from three participant groups obtained for the two isointertial tests. Data showed as mean ± standard deviation. ** - Significant differences at p < 0.01.

DISCUSSION

Within the present study, we tested various modalities of leg power in basketball players of different qualitative levels. It is important to emphasize that the participants were members of clubs ranked in the top 5 in the league they compete in (Elite – ABA League, Sub-elite – First League of Serbia, and Amateur – Second League of Serbia). Also, we recognized several patterns of movement associated with power. Therefore, three types of power tests were used: Sprint tests, jumping ability tests, and isoinertial tests on the leg extension and leg curl machine. All tests showed differences between the Elite group on the one hand, and the Sub-elite and Amateur group on the other, pointing out the importance of power in basketball performance (Ziv & Lidor, 2009; Hoffman, Epstein, Einbinder and Weinstein, 1999).

Our results suggested that acceleration does not distinguish any competitive level which is in agreement with some earlier research (Koklu, Alemdaroglu, Kocak, Erol and Findikoglu, 2011; Abdelkrim, Chaouachi, Chamari, Chtara and Castagna, 2010). At the same time, it is unexpected because most sprints during the game last 1-2 seconds (Castagna, Chaouachi, Rampinini, Chamari and Impellizzeri, 2009). Also, previous research even recommended using short sprints in fitness programs and testing (Delextrat and Cohen, 2008; Hoare, 2000). Nevertheless, short sprints show a tendency for significance (p=0.073), which requires further research. On the other hand, maximal speed tests (10mF and 20m) seem to have greater influence in the high-level game than acceleration, which is contrary to the previous studies (Koklu, Alemdaroglu, Kocak, Erol and Findikoglu, 2011; Delextrat and Cohen, 2008). This finding can be of great importance, especially when considering the correlation of the 20m sprint test with repeated sprint ability (Pyne, Saunders, Montgomery, Hewitt and Sheehan, 2008). Despite all the data, sprints are an important part of the training and selection of basketball players, given the predominantly anaerobic nature of the game.

Jumping performance is a key element and the most representative explosive movement in basketball, so it is not surprising that in most of the applied jumping tests, there are significant differences between players of different qualitative levels. Most of the studies revealed the same conclusion that the vertical jump capability is related to differences in skill level (Hoare, 2000; Delextrat and Cohen, 2008; Koklu, Alemdaroglu, Kocak, Erol and Findikoglu, 2011; Ferioli et al, 2018). Most of the mentioned studies used just the typical countermovement jump to evaluate jumping performance. In our study, 5 different jumping tests assessing different muscle characteristics were used. Differences observed in 3 jumping tests based on a single jump without the influence of ground contact in jumping performance unequivocally indicate that maximal vertical jump discriminates quality levels of the players (Delextrat and Cohen, 2008; Koklu, Alemdaroglu, Kocak, Erol and Findikoglu, 2011). There is some evidence that these types of jumps highly correlate with repeated sprint ability, which is also an important factor in basketball performance (Stojanovic, Ostojic, Calleja-González, Milosevic and Mikic, 2012).

Both tests assessing explosive muscle power using a combination of eccentric and concentric contraction (shorter ground contact time, longer flight time) could be of great importance in a basketball game, especially in common jump situations after previously failed rebounding, missed shot under the basket, after two-leg stopping (Erčulj, Dežman and Vučković, 2004). In both tests, we can observe better results in the Elite group compared to the other two groups. Despite that fact, we have not been able to determine the significance of the drop jump test (p=0.064). The reasons for that can be found in the relatively low drop height (30cm), which may be insufficient to perform maximum abilities, especially in highly trained basketball players. On the other hand, in the rebound jump, the explosive, reactive character of the muscles comes to the fore, which is in line with previous research, suggested that lower-leg reactive/explosive power might be considered a discriminative variable in the selection of basketball players (Castagna, Chaouachi, Rampinini, Chamari and Impellizzeri, 2009).

Finally, by comparing the players in terms of the power of the knee extensors and flexors, we tried to determine the differences in the characteristics of the muscles that directly participate in performing the aforementioned movements (Rouis et al, 2015; Chaouachi et al, 2009). Furthermore, these muscles are of great interest in terms of injury prevention, especially prevention of anterior cruciate ligament injury (Dervišević and Hadžić, 2012). The observed differences in the power of these muscles characterize not only individuals who play at higher levels of competition, but also the quality and level of training in the teams at each level.

CONCLUSION

The results obtained in this study represent a significant step forward in identifying the most significant elements in basketball performance. Basketball as a game has evolved in recent decades. Rule changes have led to significant changes in the physical abilities of the players. The modern game is full of explosive activities that require faster and stronger players. This paper presented different modalities of power in performance by players of different qualitative levels. Although some expected differences were not observed, there is a clear tendency that all power representations (speed, jump and isoinertial power) presented in this paper are significant in distinguishing player quality.

We must also point out that there are indications that the team position factor could provide additional elements in discriminating qualitative levels. Certainly, at the level of centers and defenders, differences should be sought in different abilities. However, power as an ability, no matter how it is manifested, is a crucial factor in modern basketball and as such should be a key element in the selection of young basketball players.

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RAZLIKE U ISPOLJAVANJU SNAGE SENIORSKIH KOŠARKAŠA U ZAVISNOSTI OD TAKMIČARSKOG NIVOA

Eksplozivna snaga donjih ekstremiteta se smatra jednim od najdominantnijih faktora moderne košarke. Na osnovu toga pretpostavili smo da su karakteristike snage faktor koji razlikuje košarkaše različitog nivoa kvaliteta. Da bismo postavili kvalitativne nivoe, testirali smo tri ekipe košarkaša (ukupno 39 igrača), od kojih svaka učestvuje u takmičenju različitog ranga, od najvišeg nacionalnog (Elitni), preko drugog nacionalnog (Subelitni) do regionalnog (Amaterski) nivoa. Svaki igrač je odradio tri dela testiranja: skokove, sprint testove i izoinercijalne testove snage. Uprkos očigledno boljim rezultatima elitne grupe u sprintu u poređenju sa druge dve grupe, statistički značajne razlike primećene su samo u testovima u kojima je postignuta maksimalna brzina (10mF i 20m) (Elitni naspram Amaterski, $p<0,05$). U tri testa skokova (SJ, CMJa i RJ) uočeni su znatno bolji rezultati kod Elitne grupe igrača u poređenju sa ostalim grupama (SJ: $p<0,01$; CMJa: Elitni naspram Subelitni $p<0,05$, Elitni naspram Amaterski $p<0,01$; RJ: $p<0,01$), dok je u CMJ uočena samo razlika između elitne i amaterske grupe ($p<0,05$). U izoinercijalnim testovima snage dobijena je samo razlika za mišiće ekstenzore kolena (Elitni naspram Amaterski $p<0,05$). U skladu sa rezultatima, može se potvrditi da je snaga kao sposobnost presudni faktor u košarkaškim aktivnostima i da treba da bude ključni element u odabiru mladih košarkaša.

Ključne reči: *nivo kvaliteta, učinak, sprint, skokovi, selekcija*

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Research article

THE RELATIONSHIP BETWEEN HORIZONTAL AND VERTICAL PLYOMETRIC JUMPS WITH SPRINT ACCELERATION

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Abstract. *The aim of the study was to determine the correlation between horizontal and vertical plyometric jumps with sprint acceleration (SA) in sprint distances of 10 and 30 meters. Six horizontal and six vertical plyometric tests were used with 44 male and 22 female trained athletes of different sports. A correlation analysis was used to determine the association between horizontal and vertical plyometric jumps with SA. The results showed a greater degree of correlation between horizontal plyometric tasks and SA than vertical plyometrics. The number of correlations of horizontal and vertical jumps with SA was significantly higher in the male subsample. For male participants, the highest correlation coefficients of two unilateral horizontal single-leg jumps could be determined for the 10-meter sprint (r=-.542; r=-.465), as well as the 30-meter sprint (r=-617; r=-.617). In the female subsample, unilateral single-leg jumps had statistically insignificant correlations with sprint speed, except for the 30-meter sprint test (r=-.641). Significant correlations to SA in both subsamples also included the standing triple jump and the bounce triple jump - 25 cm. The standing triple jump results for women showed the highest correlation with SA across all tests (r=-.663). Horizontal bilateral jumps, horizontal double-leg jumps, and the standing long jump had an important correlation with the results of the 30-meter sprint. Starting acceleration for very short distances is a very complex motor task, which depends not only on the strength of the lower extremities, but also largely on inter-muscle coordination, running biomechanics, and undoubtedly, the morphological constitution of the athlete.*

Key words: *Plyometrics, Horizontal Jumps, Vertical Jumps, Correlation, Sprint Acceleration*

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INTRODUCTION

Power is currently one of the most thoroughly researched biomotor skills in the field of kinesiology, although there are still many unanswered questions in this area of research. Power is one of the most important biomotor skills in predicting results in various sports disciplines. It can be classified according to different criteria. Based on the neuro-muscular aspect, power manifests itself in the form of isometric contractions, concentric, eccentric, or eccentric-concentric contractions (Cavagna, Komarek, & Mazzoleni, 1971; Cavagna & Citterio, 1974; Bobbert, Huijing, & van Ingen Schenau, 1987; Golhofer & Kyrolainen, 1991; Bosco, 1992; Komi, 2000; Enoka 2003). An isometric contraction happens in situations when the force of the muscle is equal to the external force, so there is no movement between the attachment sites of the muscle. Eccentric contraction occurs under conditions when the external load is greater than the force of the activated muscles. In real-life motor situations, however, the eccentric-concentric type of muscle contraction is most commonly manifested in the form of vertical or horizontal jumps. The main feature of jumps is the utilization of elastic energy in an eccentric-concentric cycle of muscle exertion. The contribution of the elastic characteristics of the musculoskeletal complex depends on the transition from eccentric to concentric contraction. The transition must be as short as possible, but certainly shorter than 200 milliseconds (Schmidtbleicher, 1992; Newton & Kramer, 1994; Komi & Golhofer, 1997; Hennessy & Kilty, 2001; Tomasevicz, Hasenkamp Ransone & Jones, 2019). This mode of muscle contraction results in less chemical energy being consumed for the same amount of mechanical work, which enables a greater amount of force to be generated than a concentric contraction alone. If the concentric contraction phase follows the eccentric phase fast enough, then the elastic elements release the accumulated energy into kinetic and mechanical work at the beginning of the concentric phase, which is manifested in greater muscle force (Komi & Nicol, 2000).

Movement structures that occur in specific motor situations are related to different contributions of eccentric and concentric muscle contractions. Often, the goal of training is to modify the eccentric muscle contraction according to its neural characteristics. Understanding the role of eccentric muscle contraction during sports activities allows us to adapt the chosen training tools appropriately. The eccentric-concentric cycle resulting from stretching of the muscle due to an external force and shortening during the second phase is called the stretch-shortening cycle (SSC) (Bosco 1992; Komi & Gollhofer, 1997; Nicol, Avela, & Komi, 2006). In the eccentric phase, a certain amount of elastic energy is stored in the muscular tendon complex that can be used in the second phase. During jumps, elastic potentiation (Bosco, Vittori, & Matteuci, 1995) is accumulated in muscle-tendon tissue mainly in the m. quadriceps, m. gastrocnemius medialis, lateralis, and the calcaneal tendon. Part of the elastic energy that is accumulated in the muscle and tendon is only available for a certain amount of time. This time is defined by the timeframe of the presence of transverse bridges within muscle fibers and lasts 15 to 120 milliseconds (Cavagna & Citterio, 1974; Enoka, 2003). The shorter the eccentric contraction, the higher the likelihood that the stretch reflex will activate to a greater degree. From the point of view of force production, it is essential that the muscle develops a greater amount of force during eccentric contraction and uses less chemical energy than during concentric contraction (Komi & Gollhofer, 1997; Enoka, 2003; Maloney, Turner, & Fletcher, 2014). The efficiency of the eccentric-concentric contraction is also affected by the switching time. The longer this switching time is, the lower the contraction efficiency. In addition to the size and speed of change in muscle length, as well as switching time, preactivation is very important for the efficiency of eccentric-concentric contractions (Schmidtbleicher, 1992). This preactivation defines the foot's first contact with the ground. Preactivation activates the efficiency of the elongation reflex and is manifested in the number of transverse bridges in muscle fibers and changes in the excitation of the ά -motor nerves. Both factors result in increased short-range stiffness. The greater the short-range stiffness of the muscle, the more pronounced the stretching of the ligaments and tendons, which results in less chemical energy consumption in the muscle. Reduced chemical energy consumption is especially crucial in movement situations where certain movements need to be performed at high speeds (i.e., ankle joint action during sprinting, push-off action for the long jump, high jump, bounce triple jump - 25 cm).

Depending on biomechanical modality, two types of jumps occur most commonly in sports situations in the vertical and horizontal directions. The neuromuscular mechanisms are similar. The difference is in their unilateral or bilateral execution and the different vectorial direction of the forces. A method of training that predominantly utilizes jumps was named plyometric training by the Soviet author V. Zatsiorsky (1966) and was scientifically established by the Soviet author Y. Verhoshanski (1968). Verhoshanski referred to this method of training as the "shock method," wherein the primary means of training were drop jumps. Plyometric training has become a mandatory component of strength and conditioning training of athletes in various sports fields. Later, the Finnish author P. Komi (2000) scientifically upgraded this method and called it "reactive neuromuscular training." The basic principle of this method is based on the function of the stretch reflex, where the muscle fibers in the muscle are activated. The stretching reflex causes contraction of the muscles that are elongated and thus prevents the antagonist muscles from contracting. In addition to stretching, receptors that are sensitive to stretching speed are present. The faster the eccentric contraction of the muscle, the greater the activity of the stretch reflex (Marković & Mikulić, 2010; Tomasevicz et al., 2019).

Vertical and horizontal jumps are essential training aids in power training for athletes in various sports. They improve the function of the eccentric and concentric muscles of the lower extremities. At the same time, these jumps are an indispensable instrument for diagnostic power measurements. Depending on the movement structure, vertical and horizontal jumps are very similar to real-life motor situations in sports practice. Many researchers (Mero, Luhtanen, & Komi, 1983; Mero, 1988; Glize & Laurent, 1997; Hennessy & Kilty, 2001; Rimmer & Sleivert, 2002; Liebermannin & Katz, 2003; Cronin & Hansen, 2005; Maulder, Bradshaw, & Keogh, 2006; Marković & Mikulić, 2010; Bishop, Read, Lake, Chavda, & Turner, 2018) have found a high correlation of vertical and horizontal jumps with sprint speed.

Sprint speed is one of the most important categories in many sports (Spencer, Bishop, Dawson, & Goodman, 2005; Loturco et al., 2015). Based on analyses of movement situations such as football, basketball, handball, volleyball, and tennis, sprint acceleration is essential over relatively short distances of 5 to 30 m. Researchers (Mero, Komi, & Gregor, 1992; Delecluse, Coppenolle, & Goris, 1995; Harland & Steele, 1997) define the first sprint phase from 0 to 10 m as the initial phase of sprint acceleration and the sprint from 10 meters to 30 meters as the transitional phase of sprint acceleration. Spencer and associates (2005) found that the average length of sprints in football (European Champions League) is 5 to 20 meters; the number of these sprints is 200 to 260. Top basketball players perform 150 - 180 sprints over a distance of 5 to 8 m (Scalan, Dascombe, & Reaburn, 2012); similar values are present in handball (Chelly et al., 2011). Top tennis players average 180 - 230 sprints over a distance of 5 to 15 meters (Ferauti, Pluim, & Weber, 2001).

Sprint acceleration, as the first derivative of sprint speed, is defined by the frequency and length of the stride. Both parameters increase up to 20 - 30 m. The stride length depends on the length of the lower extremities and the impulse of the ground reaction force. According to biomechanical studies by some authors (Mero, 1988; Mero et al., 1992; Delecluse et al., 1992; Mero & Komi 1994; Harland, & Steele, 1997; Novacheck, 1998; Mackala, Stodolka, Siemienski, & Čoh, 2012), the sprinting step is defined by the shortest possible contact phase which consists of two related sub-phases: the braking phase and the propulsion phase. The primary criterion for effective sprint acceleration is the smallest impulse of force in the braking phase and the largest impulse in the propulsion phase (Mero & Komi, 1994; Tidow & Weimann, 1994). The average step contact time in the first 10 meters of starting acceleration is 120 to 160 milliseconds for top athletes (Harland & Steele, 1997; Novacheck, 1998; Čoh, 2008). The second parameter of sprint speed is step frequency, which is mainly dependent on the regulation of the central nervous system function, especially the conduction of neuro-muscular synapses under conditions of maximal excitation (Bret, Rahmani, Dufour, Messonnier, & Lacour, 2002; Enoka, 2003, Čoh, 2019). The generation of a ground reaction force depends primarily on the motor ability of the lower extremities. It is no coincidence that sports professionals and science are looking for the most effective means and methods to develop power in sprint acceleration.

The present study aims to determine the association of horizontal and vertical jumps with the efficiency of sprint acceleration in trained athletes at a sprint distance of 10 meters and a distance of 30 m.

METHODS

Participants

The study included 44 male and 22 female second-year students of the Faculty of Sport in Ljubljana, University of Ljubljana. They were active athletes who trained at least five times a week. They competed in the following sports: football, tennis, handball, basketball, and volleyball. The average height for men was 182.15 cm (± 6.35 cm) and 167.05 (± 5.49 cm) for women. The average body weight for men was 78.36 kg (± 8.00 kg) and 63.24 kg (± 6.60 kg) for women. The average age for men was 21.26 years (± 1.78) and 20.18 (± 1.28) for women. The participants did not have any injuries to their locomotor system at the time of measurement. They were informed of the purpose and objectives of the research study, agreed with, and gave written informed consent in accordance with the Declaration of Helsinki-Tokyo. The participants understood that taking part in the study was voluntary and that they may terminate their participation at any time. The study was approved by the Ethics Committee of the Faculty of Sport, University of Ljubljana

Statistical Analysis

We used SPSS software for statistical analysis of the results. Basic descriptive parameters were calculated for all tests. A correlation analysis was used to determine the relationships between horizontal and vertical plyometric jumps with sprint acceleration in trials of 10 meter and 30-meter sprints. The significance of the associations was determined at a level of 5% and 1% risk.

Procedures

Measurements were taken over 15 days. During one testing set (approx. 1 hour), the participants were allowed to perform a maximum of 3 tests. After a 15 min warm-up session, the participants were informed of how the tests would proceed and were given a demonstration of the task. Each test was performed three times. The best result was selected for statistical analysis. Participants had a 2-3 minute break between repetitions. The breaks between tests were from 5-10 minutes. Testing was carried out in the gym of the Faculty of Sport; environmental conditions were optimal, the floor of the gym was tartan. Variables are given as follows:

Variable	Acronym
Standing triple jump	STJ
Bounce triple jump - 25 cm	BTJ25
Horizontal double-leg jumps 5	HDLJ5
Standing long jump	SLJ
Horizontal single-leg jumps - left	HSLJ10mL
Horizontal single-leg jumps - right	HSLJ10mR
Squat jump	SJ
Countermovement jump	CMJ
Drop jump 30 cm	DJ30
Drop jump – time of contact phase	DJ30s
Drop jump - 60 cm	DJ60
Drop jump – time of contact phase	DJ60s
Drop jump - 20 cm	DJ20
Drop jump – time of contact phase	DJ20s
Drop jump - 40 cm	DJ40
Drop jump - time of contact phase	DJ40s
Continuous jumps/ flight time	CON-15/F
Continuous jumps/ contact time	CON-15/C
Continuous jumps/ jump height	CON-15/V
Sprint acceleration at 10 m	SPRI 10m
Sprint acceleration at 30 m	SPRI 30m

Squat jump (Figure 1 A)

As stated by the standard testing protocol (according to Bosco, 1992), a vertical jump is performed from a static position, with the knee at about a 90º angle. The participant pushed-off as high as possible. The jump was performed without the help of the arms, which were held at hip level. The Kistler Type 9286A bipedal tensiometric platform was used in the measurement procedure. The participant was given precise instructions on how to perform the test. The participant had one trial jump and two test jumps with result measurements. The participant took a 2-3 minute break between the two test jumps. The participant's best result was used for analysis.

Countermovement jump (Figure 1 B)

The test was performed by rapidly lowering the body's central point of gravity, stretching the active leg muscles (eccentric contraction). Subsequently, the movement was stopped and the body immediately pushed vertically upwards (concentric contraction). The jump was performed with hands-on hips. The maximum jump height was measured and the measurement procedure was identical to that of the squat jump.

Fig. 1 (A, B) Measurement protocol for squat jump and countermovement jump

Drop jump (Figure 2)

The participant jumped off a bench (the bench height for men was 30 cm and 60 cm, for women it was 20 cm and 40 cm) onto a tensiometric platform (Bilateral Tensiometric Platform S2P, Ljubljana, Slovenia). Immediately after landing, the participant tried to push-off as quickly and as high as possible in the vertical direction. The participant was given precise instructions on how to perform the jump. The task was performed with hands-on hips. The participant had one trial jump and two test jumps measuring their result. The break between jumps was 2-3 min. The participant's best result was considered for analysis.

Fig. 2 Measurement protocol for drop jump 40-60 cm

RESULTS

Based on statistical parameters (Tables 1 and 2), the characteristics of the motor space of horizontal and vertical plyometrics along with sprint acceleration of the study participants were determined. Representational tasks of horizontal plyometrics were STJ, BTJ25, HSLJ10mL, HSLJ10mR, HDLJ5, and SLJ, while vertical plyometrics were represented by SJ, CMJ, DJ30, DJ30s, DJ60, DJ60s, DJ20, DJ20s, DJ40, and DJ40s. The variability of the results for horizontal jumps was slightly higher, especially for men. The correlation matrix (Table 3) shows the correlation between horizontal and vertical plyometrics tests with sprint acceleration. For athletes, sprint acceleration at 10 meters has five statistically significant associations with horizontal and vertical plyometric tasks. Nine horizontal and vertical plyometric tests have an important association with sprint acceleration at 30 meters. For female athletes, the plyometric test set was less related to sprint acceleration at 10 and 30 meters. The total number of statistically significant correlations was nine. The highest correlation coefficients for the 10 meter and 30-meter sprint were found for HSLJ10L, HSLJ10R, STJ, BTJ25, DJ30, and DJ60. The highest correlations with the 10m and 30m sprint were shown for the STJ, SLJ, HDLJ5, CMJ, and SJ plyometrics tests in the female subsample. In general, the relationship between plyometric tests and sprint acceleration was stronger for the 30-meter sprint for both sexes.

Table 1 Basic statistics of horizontal and vertical plyometric jumps and sprint acceleration for the 10 m and 30 m sprint (men)

Variable	Units	Min	Max	Mean	SD
STJ	m	6.60	8.85	7.43	0.55
BTJ25	m	6.27	8.73	7.41	0.54
HSLJ10mL	s	2.08	2.73	2.33	0.14
HSLJ10mR	s	2.07	2.72	2.34	0.15
HDLJ5	m	10.74	15.45	13.08	0.92
SLJ	m	2.32	3.08	2.60	0.17
SJ	m	0.19	0.48	0.35	0.06
CMJ	m	0.27	0.56	0.38	0.07
DJ30	m	0.14	0.38	0.29	0.06
DJ30s	s	0.16	0.27	0.19	0.03
DJ60	m	0.18	0.42	0.30	0.06
DJ60s	s	0.16	0.33	0.21	0.21
CON-15/F	s	0.39	0.59	0.48	0.04
CON-15/C	s	0.16	0.24	0.19	0.02
CON-15/V	m	0.19	0.43	0.28	5.11
SPRI 10m	s	1.67	2.09	1.84	0.09
SPRI 30m	s	3.95	4.94	4.30	0.17

Legend: STJ - standing triple jump, BTJ25 - bounce triple jump - 25 cm, HDLJ5 - horizontal double-leg jumps 5, SLJ - standing long jump, HSLJ10mL - horizontal single-leg jumps - left, HSLJ10mR - horizontal single-leg jumps - right, SJ - squat jump, CMJ - countermovement jump, DJ30 - drop jump 30 cm, DJ30s - drop jump – contact phase time, DJ60 - drop jump 60 cm, DJ60s - drop jump - contact phase time, CON-15/F - continuous jumps/ flight time, CON-15/C - continuous jumps/ contact time, CON-15/V- continuous jumps/ jump height, SPRI 10m - sprint acceleration at 10 m, SPRI 30m – sprint acceleration at 30 m, SD – standard deviation.

Table 2 Basic statistics of horizontal and vertical plyometric jumps and sprint acceleration for the 10 m and 30 m sprint (women)

Variable	Units	Min	Max	Mean	SD
STJ	m	5.30	6.96	6.14	0.40
BTJ25	m	5.31	7.04	6.36	0.41
HSLJ10mL	s	2.47	3.18	2.74	0.18
HSLJ10mR	s	2.42	3.04	2.73	0.17
HDLJ5	m	9.35	12.00	10.81	0.57
SDM	m	1.98	2.40	2.15	0.09
SJ	m	0.18	0.41	0.26	0.05
CMJ	m	0.20	0.44	0.28	0.05
DJ20	m	0.13	0.31	0.23	0.04
DJ20s	s	0.15	0.21	0.18	0.02
DJ40	m	0.16	0.32	0.25	0.03
DJ40s	s	0.155	0.257	0.194	0.23
CON-15/F	s	0.35	0.48	0.42	0.04
CON-15/C	s	0.16	0.22	0.18	0.02
CON-15/V	m	0.15	0.29	0.22	4.24
SPRI 10m	s	1.83	2.18	2.01	0.09
SPRI 30m	s	4.51	5.13	4.82	0.17

Legend: STJ - standing triple jump, BTJ25 - bounce triple jump - 25 cm, HDLJ5 - horizontal double-leg jumps 5, SLJ - standing long jump, HSLJ10mL - horizontal single-leg jumps - left, HSLJ10mR - horizontal single-leg jumps - right, SJ - squat jump, CMJ - countermovement jump, DJ30 - drop jump 30 cm, DJ30s - drop jump – contact phase time, DJ60 - drop jump 60 cm, DJ60s - drop jump - contact phase time, CON-15/F - continuous jumps/ flight time, CON-15/C - continuous jumps/ contact time, CON-15/V- continuous jumps/ jump height, SPRI 10m - sprint acceleration at 10 m, SPRI 30m – sprint acceleration at 30 m, SD – standard deviation.

Table 3 Correlation of horizontal and vertical plyometric jumps with sprint acceleration for the 10 m and 30 m sprint

	Men n= 44			Women n= 22	
Variable	SPRI 10m	SPRI 30m	Variable	SPRI 10m	SPRI 30m
STJ	-.460 **	-.599 **	STJ	-.539 **	-.663 **
BTJ25	-.416 **	-.562 **	BTJ25	-.253	-.453 *
HSLJ10mL	.542 **	.617 **	HSLJ10mL	.239	.389
HSLJ10mR	.465 **	.606 **	HSLJ10mR	.437	.641 **
HDLJ5	-.225	-.451 **	HDLJ5	-.399	-.533 **
SDM	-.181	-.461 **	SDM	-.510 *	-.659 **
SJ	.017	-.303 *	SJ	-.234	-.490 *
CMJ	-.015	-.296	CMJ	-.352	-.591 **
DJ30	-.343 *	-.451 **	DJ20	-.037	-.205
DJ30s	.091	.108	DJ20s	-.381	-.065
DJ60	-.253	-.437 **	DJ40	-.057	-.146
DJ60s	.242	.181	DJ40s	-.222	-.005
CON-15/F	-,486 **	-.528 **	CON-15s/F	-.056	-.303
CON.15/C	.122	.176	CON-15s/F	-.495 *	-.195
CON-15/V	-.481**	-.532 **	CON-15s/V	-.065	-.313

Legend: * significant correlation p<0.05, ** significant correlation p<0.01

DISCUSSION

Undoubtedly, sprint speed is an important generator of success in many sports, especially in disciplines where it is necessary to develop speed over a short distance of 5 to 30 meters. Sprint acceleration thus defined is an important performance category in football, handball, volleyball, basketball, rugby, baseball, and tennis (Mohr, Krustrup, & Bangsbo, 2003; Spencer et al., 2004; Loturco et al., 2015). In light of this fact, a logical question arises: In what ways and by what means can this ability be developed in the training process? Some studies have shown a significant association between vertical jumps (countermovement jumps, drop jumps) and sprint acceleration (Bobbert & Ingen Schenau, 1988; Hennessy & Kilty, 2001; Liebermannin & Katz, 2003; Cronin & Hansen, 2005; Maulder et al., 2006). The aim of our study was to determine how horizontal and vertical plyometric jumps relate to and affect sprint acceleration. Based on the results in Table 3, we can conclude that the horizontal jumps set had a stronger association with sprint acceleration than the set of vertical jumps. For male participants, the highest correlation coefficients of two unilateral horizontal jumps (HSLJ10mL and HSLJ10mR) were determined for the 10 meter (r=-.542; r=-.465) and 30 meter (r=-.617; r=-.617) sprints. The strong association is based on a similar biomechanical movement pattern. Sprinting, as a natural human movement, is essentially a series of jumps in a horizontal direction (Luhtanen & Komi, 1980; Mero et al., 1992). For both movement patterns, the key element is the development of ground reaction force under eccentric-concentric conditions of neuro-muscular action. Horizontal jumps are an important training tool and, at the same time, a diagnostic method for determining the push-off force of the lower extremities of sprinters. The basic criterion for effective sprint speed is to maximize the ground reaction force of the contact phase of the sprinting step as quickly as possible (Mann & Sprague, 1980; Donatti, 1995; Mero et al., 1992; Mero, Kuitunen, Harland, Kyrolainen, Komi, 2006; Čoh, 2008). Contact time for top sprinters is 80 to 95 milliseconds at ground reaction force values over three to four times the athlete's body weight (Novacheck, 1998; Mero et al., 1992). The movement structure in jumps and sprinting is very similar in terms of muscular contraction. The transition from eccentric to concentric contraction (stretch-shortening cycle needs to be as short as possible (Bosco, 1992; Bosco et al., 1995; Komi & Nicol, 2000). At the same time, a high degree of symmetry between the dominant and non-dominant legs was observed in the sample of our study participants. The mean values of the horizontal jumps at 10 meters on the left leg (HSLJ10mL) and 10 meters on the right (HSLJ10mR) were identical (2.73 seconds).

The same situation could not be found for the female participants. Horizontal jumps on the left and the right leg showed a relatively low association with sprint acceleration. Only one statistically significant association of HSLJ10mR with SPRI10m (r=.641) was found. The test may have been too demanding in terms of the training level of the participants, or it may have been due to a lack of task performance technique.

The standing triple jump (STJ) and the bounce triple jump - 25 cm (BTJ25) tests, as representative of unilateral horizontal jumps, showed a high correlation with sprint acceleration, especially for the 30-meter sprint (SPRI30m: STJ, r=-.599; SPRI30m: BTJ25, r=-.562). Sprint acceleration for the 30-meter sprint (SPRI30m) was also highly associated with the standing triple jump (STJ, r=-.663) in the female subsample. For the female participants, this association demonstrated the highest correlation across all horizontal and vertical plyometric tests with start speed. The standing triple jump is one of the standard, reliable, and valid tests in the field of push-off force diagnostics for athletes of different sports.

Based on this strong relationship, we can deduce the effectiveness of these training tools on starting speed. Using these tasks, push-off force is developed, which directly affects stride length. This stride length increases progressively to a distance of 15 meters during start acceleration (Delecluse et al., 1992; Mero & Komi 1994; Harland, & Steele, 1997; Novacheck, 1998; Čoh, 2008). At the same time, step frequency, which depends largely on the contact times of the foot with the ground, increases. The average contact time within the first 10 meters of sprint acceleration in athletes is 120 to 160 milliseconds (Mero et al., 1992; Harland & Steele, 1997; Donatti, 1995; Novacheck, 1998; Čoh, 2008). In our sample, the contact times of the drop jumps were of similar values, varying between 150 and 210 milliseconds (Tables 1 and 2).

The standing long jump (SDM) and horizontal double-leg jump (HDLJ5) tests represent bilateral jumps in the horizontal direction. The former correlates highly with sprint acceleration at 30 meters in both male and female participants, especially in women (SDM: SPRI30m, r=-.659). The movement pattern is different, but the neuro-muscular performance is similar. The force production for the standing long jump and starting acceleration is based on eccentric-concentric muscle contraction. The movement structure of the tasks varies in terms of kinematics and dynamics. A standing long jump is a good indicator of force gradient (Buhrle, Schmidtbleicher, & Ressel, 1983). The force impulse value is equal to the area under the force-time curve, and this parameter best defines the distance of the jump and push-off velocity, which is an important parameter of sprint speed. Surprisingly, the standing long jump was unrelated (r=-.181) to the initial sprint acceleration at 10 meters in the male subsample. Perhaps, the result at this stage of the sprint was more a reflection of contamination of the running technique than power.

The horizontal double-leg jump (HDLJ5) test had statistically significant correlations with sprint acceleration at a distance of 30 meters (SPRI30m) in both subsamples (men r=-.451; women r=.-533). However, no statistically significant correlation could be established for the 10-meter sprint (SPRI10m). Horizontal double-leg jumps belong to the group of "classic" exercises for power training for athletes. Again, it can be concluded that the start speed of a relatively short distance 10-meter sprint is more dependent on biomechanical parameters, in particular the coordination of power and control of running technique. An essential factor in starting speed is the optimization of step frequency and stride length. This relationship is determined by an individual's neuro-muscular regulatory processes of movement, morphological characteristics, biomotor abilities, and biochemical energy resources (Delecluse et al., 1992; Mero & Komi 1994; Harland & Steele, 1997; Novacheck, 1998; Prampero et al., 2005; Mackala 2007). Stride length depends on the length of the lower extremities and the impulse of the ground reaction force. According to biomechanical studies by some researchers (Bruggemann & Glad, 1990; Mero et al., 1992; Donatti, 1995), the sprinting step is defined by the optimal execution of the contact phase, which consists of two related sub-phases: the braking phase and propulsion phase. The basic criterion for efficient sprint acceleration technique is to minimize the force of the inhibitory phase and maximize the force of the propulsive phase (Mero et al., 1983; Mero & Komi, 1994). The second parameter of sprint acceleration is step frequency, which is largely dependent on the regulation of the central nervous system, especially the conductance of neuro-muscular synapses under conditions of maximal excitation (De Luca, 1997; Enoka, 2003; Mero et al., 2006). A high step frequency requires precise and regulated activation and deactivation of agonistic and antagonistic lower extremity muscle groups.

Vertical jumps are the second set of plyometric tests included in the study to determine their association with sprint acceleration. We used the standard test battery, according to Bosco (1992): the squat jump (SJ), countermovement jump (CMJ), continuous vertical jumps (CON15), and drop jump (DJ). Using a bipedal tensiometric platform (Kistler Type 9286A), jump height was determined and recorded, along with the contact time of the drop jumps.

The squat jump (SJ) had a relatively modest relationship with sprint acceleration. For both sub-samples, it only affected the 30 meter sprint acceleration (men r=-.303; women r=-.490). The countermovement jump also correlated significantly only with the women's 30-meter sprint (r=-.591). The vertical squat jump is performed from a static position, with knees bent to about a 90 º angle. This position eliminates the influence of elastic energy in the muscles and tendons as well as in reflex mechanisms that further activate the muscles (Komi & Nicol, 2000; Nicol et al., 2006). The squat jump is performed without the help of one's arms, which are held at hip height. The test evaluates the concentric component of push-off force. The average jump height for men was 0.35 meters, and 0.26 meters for women.

The countermovement jump (CMJ) also showed a single characteristic that correlated with the 30-meter sprint in women (r=-.591). The same applied to drop jumps. The results of our study were surprising. To date, studies have shown a high correlation between vertical jumps and sprint speed (Hennessy & Kilty, 2001; Liebermannin & Katz, 2003; Marković, Dizdar, Jukić, & Cardinale, 2004; Cronin & Hansen, 2005; Maulder et al., 2006; Mero et al., 2006). Vertical jumps and drop jumps are an essential form of strength and conditioning in athletes. They improve the function of the eccentrically concentric lower extremity function and muscle stiffness. In addition, these jumps are one of the most important diagnostic tools for evaluating an athlete's push-off force.

The countermovement jump is performed by rapidly lowering the body's central point of gravity, causing the active muscles of the legs to stretch (eccentric contraction). The movement is then stopped and immediately pushed-off vertically upwards (concentric contraction). The energy stored in the muscles and tendons during stretching is transferred to the concentric phase. This results in a higher speed of movement in the second phase. The neuromuscular jumping mechanism is based on the utilization of elastic potentiation accumulated in the muscular tendon complex (Komi, 2000). The jump height difference between squat jumps and countermovement jumps was 0.03 meters for men and 0.02 meters for women. This result shows that the athletes in our sample utilized the elastic potential of the muscular tendon system poorly. According to some research, the height of the countermovement jump is expected to exceed the height of the squat jump by 0.08 to 0.15 meters (Komi, 2000; Baechle & Earle, 2008; Marković & Mikulić, 2010).

Drop jumps are often a means of training for better push-off force in athletes of various sports due to their positive effects on the musculoskeletal and tendon systems, as well as neuromuscular function (Komi, 2000). The inclusion of drop jumps in the training process depends largely on an athlete's training experience. Young athletes should be cautious to avoid possible injuries. In the present study, male participants performed jumps from heights of 30 cm and 60 cm, while women completed the tests from heights of 20 cm and 40 cm. Given the correlation coefficients in the male subsample, significant correlations between the 30 cm drop jump and 60 cm drop jump with sprint acceleration were found. No significant relationship could be identified within the female subsample. The 30 cm drop jump had a significant correlation with both the 10-meter sprint (r=-. 343) and the 30-meter sprint (r=-.451). The 60 cm drop jump, however, only correlated with the 30-meter sprint (r=-.437), while the association with the 10 m sprint was insignificant (r=-.235). As part of the drop jump test measurements, contact times were also determined using a tensiometric platform. These results indicated the stiffness and speed of the eccentric-concentric muscular tendon cycle. The continuous jumps test also has statistically significant correlations with both the 10 meter sprint (r=-.481) and the 30 meter sprint (r= -.532).

Research, to date, has shown a significant correlation between drop jumps and sprint speed (Rimmer & Sleivert, 2000; Young, 1995; Maulder et al., 2006; Marković & Mikulić, 2010). The neuromuscular mechanisms involved in performing the drop jump and sprinting step are very similar. The faster the elongation of the muscular tendon complex, the shorter the time and the greater the amount of elastic energy. It is a well-known fact that the musculoskeletal complex (the calcaneal tendon, m. gastrocnemius medialis, m. gastrocnemius lateralis, m. soleus), under conditions of higher velocity of the eccentric-concentric cycle, can store more kinetic energy in the form of elastic energy (Bobbert et al., 1987; Bobbert, van Soest, 2000; Komi, 2000). Part of the elastic energy is available for only 0.160 to 0.180 seconds, i.e., for the duration of the muscle fibers' transverse bridges (Enoka, 2003). Elastic energy generation also means shorter contact times, which is a decisive factor in sprint acceleration.

The average contact time for the 30 cm drop jump, in the subsample of male participants, was 0.190 seconds and 0.210 seconds for the 60 cm drop jump. According to research (Komi, 1984; Gollhofer & Kyrolainen, 1991; Schmidtbleicher, 1992), a key mechanism of short contact time under conditions of an eccentric-concentric cycle (stretch-shortening cycle – Komi & Nicol, 2000) is the effective preactivation of agonists and synergists of the ankle joint (m. gastrocnemius lateralis, m. gastrocnemius medialis, m. soleus, and m. tibialis). Agonists and synergists provide increased stiffness of the ankle joint, which depends on joint stiffness regulation, which controls and synchronizes the functioning of flexors and extenders of the feet before contact with the ground (Gollhofer & Kyrolainen, 1991; Nicol et al., 2006). In the case of explosive motor structures, including sprinting, the time available to generate force is one of the most critical limiting factors. The contact times of the study participants, which were, on average, shorter than 0.200 seconds (Table 1 and Table 2) did not otherwise show statistically significant association values with sprint acceleration; however, their values did ensure the effective performance of drop jumps. These are indisputably an essential means of sprint acceleration training. Surprisingly, no statistically significant correlation between drop jumps and start speed could be found for the female participants of our study. This result may be due to the complexity of such jumps, a lack of technique, or insufficiency of stiffness in the musculoskeletal system.

CONCLUSION

The study demonstrated a strong correlation between two biomotor abilities: sprint acceleration and plyometric power. Properly integrated into the training process, horizontal and vertical jumps are an indispensable means of developing athletes' speed in various sports. Their effect is especially important in movement patterns where it is necessary to develop as much speed as possible over as short a distance as possible. At the same time, horizontal and vertical jumps are also a reliable and objective diagnostic instrument for planning the power training process of athletes. We found that jumps in the horizontal direction, especially unilateral, had a higher correlation with start acceleration than vertical jumps. This relationship is due to their similar kinematic and dynamic structure. Horizontal and vertical plyometric jumps have a greater effect on transitional sprint acceleration in the 30-meter sprint than on initial sprint acceleration in the 10-meter sprint. Starting acceleration for very short distances is a very complex motor task, which depends not only on the strength of the lower extremities, but also largely on inter-muscle coordination, running biomechanics, and undoubtedly, the morphological constitution of the athlete. We can conclude that plyometric training is an extremely important tool for the training process of athletes in terms of sprint speed development.

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ODNOS HORIZONTALNIH I VERTIKALNIH PLIOMETRIJSKIH SKOKOVA SA SPRINTERSKIM UBRZANJEM

Cilj studije bio je da se utvrdi korelacija između horizontalnih i vertikalnih pliometrijskih skokova sa sprinterskim ubrzanjem na udaljenostima od 10 i 30 metara. Korišćeno je šest horizontalnih i šest vertikalnih pliometrijskih testova sa 44 muškaraca i 22 žena, treniranih sportista različitih sportova. Korelacionom analizom je utvrđena povezanost horizontalnih i vertikalnih pliometrijskih skokova sa sprinterskim ubrzanjem. Rezultati su pokazali veći stepen korelacije između horizontalnih pliometrijskih zadataka i sprinterskog ubrzanja, u odnosu na vertikalnu pliometriju. Broj korelacija horizontalnih i vertikalnih skokova sa sprinterskim ubrzanjem bio je značajno veći u poduzorku muškaraca. Kod muških ispitanika, najveći koeficijenti korelacije dva unilateralna horizontalna skoka jednom nogom utvrđeni su za sprint na 10 metara (r=-.542; r=-.465), kao i za sprint od 30 metara (r=-617; r=-.617). U poduzorku žena, nisu utvrđene statistički značajne korelacije unilateralnih skokova jednom nogom sa brzinom u sprintu, osim u testu sprinta na 30 metara (r=-.641). Značajne korelacije sa sprinterskim ubrzanjem u oba poduzorka takođe su uključivale troskok s mesta i troskok - 25 cm. Rezultati troskoka s mesta za žene pokazali su najveću korelaciju sa sprinterskim ubrzanjem u svim testovima (r=-.663). Horizontalni bilateralni skokovi, horizontalni dvonožni skokovi i skok u dalj s mesta imali su značajnu korelaciju sa rezultatima sprinta na 30 metara. Ubrzanje na vrlo kratkim rastojanjima složen je motorički zadatak koji ne zavisi samo od snage donjih ekstremiteta, već i od međumišišne koordinacije, biomehanike trčanja i nesumnjivo od morfološke građe sportiste.

Ključne reči: *pliometrija, horizontalni skokovi, vertikalni skokovi, korelacija, sprinterko ubrzanje*

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Research article

RELIABILITY OF SPECIFIC TESTS OF STRENGTH OF SPORTS ARM WRESTLING

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Abstract. *The goal of the present study was to explore the reliability of a specific strength test of sports arm wrestling. The Maximal muscle force (Fmax) and maximal Rate of the muscle force development (RFDmax) for the right and left arm in a specific arm wrestling supinated and neutral position were analyzed. The sample of variables included the following two variables: Maximal voluntary force (F_{max}) and maximal voluntary explosive force, i.e., maximal Rate of force development (RFD_{max}), measured at the left (L) and right (R) arm (musculus Biceps Brachii), for both sports-specific positions – supination, and the neutral position. The Single variable Inter-test reliability was determined using the Intraclass Correlation Coefficient (ICC) and Cronbach's Alpha based on standardized items. The statistical significance level was determined on the criterion of $p \leq 0.05$. Very high reliability (ICC = 0.916-0.971) exists for maximum muscle force variables, measured for the left and right arm with supinatorial and neutral hand positions. Moderate and high reliability (ICC = 0.681-0.892) was found for explosive muscle force variables, measured with the left and right hand in supinatorial and neutral hand positions. Generally, the highest values of muscle maximal and explosive force were achieved during the first test attempt. By looking at this information, coaches and athletes, may reliably use this specific AW test to create a clearer picture of the athlete's current physical readiness and for making appropriate decisions to guide the training process.*

Key words: *Muscle Strength, Metrological Sensitivity, - Methodological Validity*

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INTRODUCTION

Muscle contractile output in sports theory, known as strength, is often equated with muscle force and can be defined as the ability of a muscle or a group of muscles to produce physical force while contracting against an external resistance (Zatsiorsky, 1995). The isometric dynamometry method is traditionally used to measure the maximal force that can be produced during a maximal voluntary contraction against a supramaximal load or resistance, while tensiometric dynamometry can be used for measuring maximal force, as well as an explosive force too (Mirkov, Nedeljkovic, Milanovic, Jaric, 2004; Marković, Dopsaj, Koprivica, Kasum, 2018). The quantitative measure of arm strength can be obtained using a different type of dynamometer, and the standard dymomometer test is known as – the Hand Grip test (Dopsaj et al., 2018; Zarić, Dopsaj, Marković, 2018; Marković, Dopsaj, Veljković, 2020; Majstorović et al., 2020; Majstorović et al., 2021). However, from the aspect of the Arm Wrestling biomechanical position, the Hand Grip cannot be considered a sports-specific test.

Arm Wrestling (AW) is considering one of the oldest sports. Paintings in an Egyptian tomb testify that this way of competition among people was popular back then in 2000 BC. The first rules and the first organized competition were set up in Petaluma (California) 60 years ago (Usanov & Gugina, 2012). AW starts reaching its glory at the end of the 20th century. AW is an individual sport where sportsmen face one another either in a tournament or a super match. The muscles of the forearm are the most important for AW , primarily wrist flexors, supinators, and pronators, secondarily elbow flexor and extensors, and thirdly shoulders muscles (Pectoralis Major, Pectoralis minor, Subscapularis, Deltoideus) and back muscles (Latissimus dorsi) (Silva et al., 2009).

Like in every other sport, AW has its techniques, the top-roll and hook. In top-rolling, the competitor tries to open the opponent's finger and wrist by pulling his/her hand, arm, and shoulder backward from the center. The main part of the hook is pushing to the center of the table and forcing the opponent's wrist in a supinated position, and one's own in the wrist flexion position with or without supination (McKay & McKay, 2009).

In AW competition, the referee who will start the match with "Ready...Go" is considered as a head referee, and the referee who watches for elbow fouls after the match starts is considered an assistant referee (World Armwrestling Federation, 2009). People watching an AW match may think that the most crucial factor for the win is maximal muscle strength. However, there are equally important abilities like technical efficiency and Rate of muscle force development, thanks to which we can put an opponent in a challenging position to defend (Song et al., 2007).

AW is a sport that requires muscle strength, predominantly of the upper body. Top-skilled arm wrestlers possess higher maximum muscle strength compared to low-skilled ones. The highest differences in strength tests exist for the forearm supinator (77.9 %), forearm pronator (52.4 %), hand flexors (51.2 %), shoulder pronator (44.3 %), hand abductor (37.3 %), supine forearm flexors (34.0 %), grip (32.1 %), and neutral-point forearm flexors (29.0 %), in favor of top-skilled arm-wrestlers (Matyushenko et al., 2020). Flexing forearm strength is higher in arm-wrestlers compared to students, who do not practice arm-wrestling, where statistically significant differences ($p < 0.05$) were found (Podrigalo et al., 2015). These finds show the importance of including exercises for strengthening (maximum and explosive force) mentioned muscles in AW training. Besides that, those muscles have an essential role in achieving success in an AW competition.

It is important to advance scientific knowledge in performance testing to design specifically adjusted training protocols and periodization models and to increase success in competition (Bridge et al., 2014; Chaabene et al., 2017). The main purposes of sport-specific testing can comprise talent identification and development of young athletes as well as the identification of strengths and weaknesses in young and elite athletes to be used for training purposes (Tabben et al., 2014). Prior to the design of a test protocol for sport-specific performance assessment, it is recommended that a systematic needs analysis be conducted to identify the demands of the specific sport (Kraemer et al., 2012). With the systematically derived information on sport-specific demands from the needs analysis, adequate sport-specific performance tests can be designed and implemented into training practice (Tabben et al., 2014). Even though there is a well-accepted advantage of sport-specific performance testing over the application of general physical fitness tests, there is no study available that systematically reviewed the methodological quality (e.g., sample size, inclusion/exclusion criteria, stability of testing conditions), validation data (i.e., reliability, validity, sensitivity), and feasibility (i.e., practicability) of the existing sport-specific tests related to AW.

Also, there are no defined AW specifics strength tests which can hint at success, and it is a requirement of sports science and methodology of sport to establish a specific test for AW.

The aim of the present study was to establish reliability of two sports specific AW strength tests with which they can be measured the Maximal muscle force (F_{max}) and Rate of the muscle force development (RFD_{max}) for the right and left arm in a supinated and neutral position. The second aim is to establish data for defining the initial quantitative values for the assessment of specific fitness of AW athletes of the national level.

METHODS

The current study was realized by applying the laboratory method of testing using tensiometric dynamometry. Testing is realized by the method of the test-retest using the trial-by-trial technique alternately with the left and right arm, where the choice of arm and pulling position for the start of the testing was randomized relative to the participants.

Participants

Eleven male participants were engaged in the study, active competitors in the sport of Arm Wrestling (AW), with the following basic training and anthropo-morphological characteristics: Age – 26.2±5.3 yrs., BH – 181.4±5.0 cm, BM – 85.5±10.7 kg, BMI – 26.00±3.24 kg/m^2, PBF – 10.84±4.72 %, PSMM – 51.33±2.72 %, and with 3.1±1.2 years of AW training. All of the participants who volunteered for the study were healthy and had no neuromuscular disorders or orthopedic dysfunctions affecting hand strength. The research was conducted according to the postulates of the Declaration of Helsinki and with the permission of the Ethics Committee of the University of Belgrade Faculty of Sport and Physical Education (02 No. 484-2).

Testing equipment

Testing of the AW sport-specific strength (i.e., maximal isometric muscle force – F_{max}, and maximal explosive force – RFD_{max}) was performed using a standardized and evaluated tensiometric probe from the Sport Medical Solution company (SMS) measurement and electronic devices company (All4gym d.o.o.; http://all4gym.rs/). The SMS probe system was used for the acquisition and in-depth analysis of the force signal, i.e., the F-t curve in basic and sports specific testing (Marković, Dopsaj, Koprivica, Kasum, 2018; All4gym d.o.o.; http://all4gym.rs/; Majstorović et al., 2021). The system measuring chain consisted of a standard load cell, an acquisition unit with an integrated 12-bit A/D conversion and signal conditioning, with installed SMS software on a laptop. The load cell (CZL301) was equipped with a full bridge strain gauge sensor located on a steel fixed structure (Figure 1). The load cells had a rated load of 2000 N, a maximum measurement error of 0.03 %, and linear dependence. The frequency of sampling of the system was set at 500 Hz. Before testing, load cell calibration was performed using laboratory weights. All measurement characteristics for the used SMS test system were evaluated as reliable and valid (Marković, Dopsaj, Koprivica, Kasum, 2018; Marković, Dopsaj, Veljković, 2020; Majstorović et al., 2020).

Testing protocol

All measurements were performed in the specific standing position using two specific arm positions (neutral and supinated) for both the left and right hand (Figure 1). The elbow is planted on the pad of the AW table; at the start, the angle in the elbow was 90 degrees or less, with a hand in a closed and neutral position, and mid-way in the fully pronated and supinated position. Figure 1 shows a neutral, while Figure 2 shows a supinated start position. Each participant had an individual 10-minute warm-up and two submaximal testing attempts with the left and right arm for familiarisation with equipment and measurement procedures. After the familiarisation procedure, each participant had a minimum of 5 minutes of rest after the experimental testing was carried out using a randomized trial-to-trial method with a pause duration of 3 minutes between the trials (Tanner and Gore, 2012). For each of the AW testing positions and arms, the participants had three test trials (Test 1, Test 2 and Test 3) and all result was taken for statistical analysis. Before the experimental measurement, all participants had light training 48 hours before, i.e., a complete rest of 24 hours before testing. All tests were performed in the Methodological Research Laboratory (MIL) at the University of Belgrade Faculty of Sport and Physical Education, between 11:00 AM and 14:00 PM on the same day.

Fig. 1 Neutral arm AW testing position

Fig. 2 Supination AW testing position

Variables

The following variables were used in the research:

Maximal voluntary force (F_{max}), measured for the left (L) and right (R) arm (*musculus* Biceps Brachii), for both sports-specific positions – supination (S) and the neutral (N) position -

1. BBS_F_{max}_L, maximal voluntary force of the biceps brachii in left hand supination, expressed in Newtons (N);
2. BBS_F_{max}_R, maximal voluntary force of the biceps brachii in right hand supination, expressed in Newtons (N);
3. BBN_F_{max}_L, maximal voluntary force of the biceps brachii in the neutral position of the left hand, expressed in Newtons (N);
4. BBN_F_{max}_R, maximal voluntary force of the biceps brachii in the neutral position of the right hand, expressed in Newtons (N).

Maximal voluntary explosive force, i.e., Rate of force development (RFD_{max}), measured for the left (L) and right (R) arm (*musculus* Biceps Brachii), for both sports-specific positions – supination (S) and the neutral (N) position -

5. BBS_RFD_{max}_L, maximal voluntary explosive force of the biceps brachii in left hand supination, expressed in Newton per second (N/s);
6. BBS_RFD_{max}_R, maximal voluntary explosive force of the biceps brachii in right hand supination, expressed in Newton per second (N/s);
7. BBN_RFD_{max}_L, maximal voluntary explosive force of the biceps brachii in neutral position of the left hand, expressed in Newton per second (N/s);
8. BBN_RFD_{max}_R, maximal voluntary explosive force of the biceps brachii in neutral position of the right hand, expressed in Newton per second (N/s).

Statistical methods

All raw data were analyzed by descriptive statistical procedures in order to define the basic results of central tendency (Mean) and data variability (standard deviation – SD, coefficient of variation – cV%, minimal or maximal data value – Min, Max., and 95% range of confidence interval of mean value – Lower and Upper Bound). Differences between test trial mean values of variables were established using the GLM Repeated Measures procedures by multiple analyses of variance. The differences of the variables between the individual attempts were determined using Post Hoc Tests multiple comparisons for observed means with Bonferroni criteria. Single variable Inter-test reliability was determined using the Intraclass Correlation Coefficient (ICC) and Cronbach's Alpha based on standardized items. ICC values from 0.50 to 0.69 are defined as moderate, from 0.70 to 0.89 as high from 0.90, and higher as very high reliability (Munro et al., 1986; Sole et al., 2007). The statistical significance level was determined on the criterion of $p \leq 0.05$ (Hair, Anderson, Tatham, Black, 1998). Statistical analyses were conducted using IBM© SPSS© Statistics Version 23.0.

RESULTS

Table 1 shows the results of the descriptive statistical analysis of the tested variables.

Variable	Test Trials	Mean	SD	cV%	Min	Max	95% Confidence Interval for Mean	
							Lower Bound	Upper Bound
BBS_F_{max} (N)	L_1	425.4	49.4	11.61	363.0	537.0	392.2	458.6
	L_2	402.7	49.8	12.37	339.0	515.0	369.3	436.1
	L_3	387.7	45.3	11.68	333.0	491.0	357.2	418.2
	R_1	401.9	39.0	9.70	342.0	457.0	375.7	428.1
	R_2	410.8	66.1	16.09	310.0	551.0	366.4	455.2
	R_3	384.8	84.7	22.01	223.0	564.0	327.9	441.7
BBS_RFD_{max} (N/s)	L_1	1743.1	264.0	15.15	1261.0	2179.0	1565.7	1920.4
	L_2	1904.1	545.5	28.65	1182.0	3043.0	1537.7	2270.5
	L_3	1489.7	467.4	31.38	1151.0	2807.0	1175.7	1803.7
	R_1	1680.0	453.4	26.99	894.0	2581.0	1375.3	1984.7
	R_2	1694.5	480.2	28.34	903.0	2777.0	1371.9	2017.1
	R_3	1586.9	420.2	26.48	828.0	2187.0	1304.6	1869.2
BBN_F_{max} (N)	L_1	378.3	51.5	13.61	274.0	491.0	343.7	412.9
	L_2	359.4	54.8	15.25	279.0	484.0	322.6	396.2
	L_3	334.8	61.3	18.31	202.0	448.0	293.6	376.0
	R_1	377.7	51.2	13.56	291.0	468.0	343.3	412.1
	R_2	351.8	52.2	14.84	255.0	421.0	316.7	386.9
	R_3	333.9	58.1	17.40	211.0	408.0	294.9	372.9
BBN_RFD_{max} (N/s)	L_1	1968.0	490.3	24.91	1306.0	2843.0	1638.6	2297.4
	L_2	1568.7	327.5	20.88	1173.0	2289.0	1348.7	1788.7
	L_3	1429.1	475.6	33.28	844.0	2638.0	1109.5	1748.7
	R_1	2063.4	577.6	27.99	1110.0	3195.0	1675.4	2451.4
	R_2	1677.4	376.9	22.47	1118.0	2262.0	1424.2	1930.6
	R_3	1527.9	477.5	31.25	783.0	2145.0	1207.1	1848.7

Table 1 shows the maximal and explosive muscle force mean values for three left-hand and right-hand attempts. It can be seen that the values of maximum muscle force for the left arm in supination was in the range from 387.7 N to 425.4 N, and for the right arm from 384.8 N to 410.8 N. Then, the maximal muscle force values for the left arm with the fist in neutral position ranges from 334.8 N to 378.3 N, while for the right hand, the range is from 333.9 N to 377.7 N. Also, the values of explosive muscle force for the left hand with the hand in supination range from 1489.7 N / s to 1904.1 N / s, and for the right hand from 1586.9 N / s to 1694.5 N / s. Then, the values of explosive muscle force for the left arm with the fist in neutral position range from 1429.1 N / s to 1968.0 N / s, while for the right, from 1527.9 N / s to 2063.4 N / s.

Based on the relative indicators of variability, it can be argued that the results for all variables are very homogeneous because the values of the coefficient of variation (cV%) range from 9.70% to 33.28% (Table 1 BBS_F_{max}_R_1 and BBN_RFD_{max}_L_3, respectively). This indicates that despite the relatively small number of participants in the sample (N = 11), the obtained descriptive and other data can be considered homogeneous in relation to the population of AW senior male athletes from the Republic of Serbia.

An analysis of Table 2 shows that in almost all observed variables there are statistically significant differences (Wilks' Lambda = 0.142-0.475, p = 0.000-0.035), except for the variable BBS_RFD_{max}_R, where no statistically significant differences were found (Wilks' Lambda = 0.874, p = 0.574). The difference between the attempts in the observed variables varies from 52.5% to 85.8% (Partial Eta^2 = 0.525-0.858), and a significantly lower difference of only 12.6% (Partial Eta^2 = 0.126) exists for the variable BBS_RFD_{max}_R. The observed power for all variables ranges from 65% to 100% (Observed power = 0.658-1.000), except for the variable BBS_RFD_{max}_R, where the observed power is only 12% (Observed power = 0.127).

Table 2 Results of differences of mean values between AW tests

Variable	Wilks' Lambda			Observed Power	Test 1 vs. Test 2	Test 1 vs. Test 3	Test 2 vs. Test 3
	Value	p sig.	Partial Eta^2				
BBS_F_{max}_L	0.406	0.017	0.594	0.784	0.032	0.010	0.123
BBS_F_{max}_R	0.321	0.006	0.679	0.914	ns*	ns*	0.037
BBS_RFD_{max}_L	0.475	0.035	0.525	0.658	ns*	ns*	0.035
BBS_RFD_{max}_R	0.874	0.547	0.126	0.127	ns*	ns*	ns*
BBN_F_{max}_L	0.142	0.000	0.858	1.000	ns*	0.000	0.029
BBN_F_{max}_R	0.186	0.001	0.814	0.998	0.045	0.001	0.005
BBN_RFD_{max}_L	0.260	0.002	0.740	0.972	ns*	0.002	ns*
BBN_RFD_{max}_R	0.355	0.009	0.645	0.867	0.020	0.005	ns*

The results of the reliability analysis showed that the value of standardized Cronbach's alpha and ICC are at the level from 0.662 and 0.681 for BBS_RFD_{max}L to 0.974, and 0.971forBBN_F_{max}_L, and that they are statistically significant (Table 3, from p= 0.014 to p=0.000, respectively). Cronbach's Alpha for the variables: BBS_Fmax L is 0.945, BBS_Fmax R is 0.955, BBN_Fmax L is 0.974, BBN_Fmax R is 0.964. In the Rate of the muscle force development test, Cronbach's Alpha values for the variables are: BBS_RFDmax L is 0.662, BBS_RFDmax R is 0.713, BBN_RFDmax L is 0.846, and for BBN_RFDmax R is 0.913. Variables: BBS_F_{max} R, BBS_F_{max} L, BBN_F_{max} R, and BBN_F_{max} L have very high reliability (ICC = 0.916, 0.944, 0.964, and 0.971, respectively). Then, the variables: BBS_RFD_{max} R, BBN_RFD_{max} L and BBN_RFD_{max} R have high reliability (ICC = 0.710, 0.835, 0.892, respectively). Only the variable BBS_RFD_{max} L has moderate reliability (ICC = 0.681).

Table 3 Results of reliability analyses between observed AW tests

	Cronbach's Alpha Based on Standardized Items	ICC – Interclass Correlation Coefficient			F test	
		Average Measures	95% Confidence Interval			
			Lower Bound	Upper Bound	Value	p sig
BBS_F_{max} L	0.945	0.944	0.845	0.984	17.91	0.000
BBS_F_{max} R	0.955	0.916	0.766	0.975	11.86	0.000
BBS_RFD_{max} L	0.662	0.681	0.115	0.907	3.14	0.014
BBS_RFD_{max} R	0.713	0.710	0.195	0.915	3.45	0.009
BBN_F_{max} L	0.974	0.971	0.920	0.992	35.56	0.000
BBN_F_{max} R	0.964	0.964	0.899	0.989	27.46	0.000
BBN_RFD_{max} L	0.846	0.835	0.543	0.952	6.07	0.000
BBN_RFD_{max} R	0.913	0.892	0.699	0.968	9.23	0.000

DISCUSSION

In this study, ICC values show moderate to very high reliability for considered muscle force variables and applied test variants (Table 3). From the abovementioned, it is evident that higher ICC values were established for the maximum muscle force of the left and right arm measured in supination and the neutral position of the hand compared to explosive muscle force values. Therefore, it can be stated that the performed test can reliably measure, i.e. detect changes of measured maximal muscle force, but less during explosive muscle force. Therefore, its use in practice can be recommended.

Sports AW requires the manifestation of maximum muscle force and explosive muscle force, which can be reliably detected for the mentioned variables by applying the examined specific test. By monitoring the mentioned variables, muscle force values can be identified in specific positions that correspond to positions during competition, primarily in the initial phase of the match. Explosive muscle force is beneficial in the initial phase (start) of the match when a particular advantage can be achieved over the opponent, who has an equal or slightly higher level of maximum muscle force and a lower level of explosive muscle force. By assessing and monitoring the mentioned variables, the identification and selection of talents can be performed, and the direction of the training process determined.

When observing individual variables, the most significant differences in attempts were noticed in the variable BBN_F_{max}_L, then, in the following order: BBN_F_{max}_R, BBN_F_{max}_R, BBN_RFD_{max}_L, BBS_F_{max}_R, BBN_RFD_{max}_R, and finally BBS_RFD_{max}. This implies that regardless of whether the attempt is performed by the left or right hand, the values of muscle forces manifested in almost all the variables are statistically significantly different ($p < 0.05$). Therefore, it is impossible to state that the dominant arm's advantage exists in muscle force values. That shows that in AW training, the training load for both arms is applied and dosed equally. In future and in-depth research, it is necessary to determine the metrological sensitivity and methodological validity of the given tests to know how many attempts and which attempt should be taken as the most representative one for measuring the given specific abilities.

By observing the individual mean values in individual tests for all attempts, the highest values in the maximum muscle force of 425.4 N were achieved with the left hand in supination in the first attempt. All maximum force values are higher for supination regarding the neutral position of the hand. That is not surprising because the m. biceps brachii is most effective when the forearm is in the anatomical position, i.e., when the radius and ulna are parallel (McMilan & Carin-Levin, 2012). The highest value of explosive muscle force of 2063.4 N/s was achieved by placing the hand in the neutral position, also in the first attempt. It seems that the effectiveness rules of m. biceps brachii do not apply to explosive muscle force regarding the position of the hand.

Also, this data indicates that AW athletes are adapted to show maximum values of both strength and explosiveness in the first attempt. The assumption is that this ability is probably very important in relation to the competitive performance in which the athlete who is able to immediately show dominance over the opponent wins, regardless of whether it is a winning strategy due to the maximum level of force achieved to ensure victory, or it is a strategy where the tactics of teasing, i.e., the sudden manifestation of maximum explosiveness achieves the advantage needed to win. Apiknar et al. (2013) point out that strength and a speedy response can enable arm wrestlers to dominate opponents using proper technique.

In order to compare mean values for all three trials of maximum force and explosive force variables from Table 1, raw scores must be converted into standard scores. Conversion can be done using Z scores and percentages. Then, the comparison between the highest values can be made. Therefore, the highest value of explosive muscle force is at 97.00%, while the maximal muscle force is at 94.26%, which is a difference of 2.74%. Thus, observing the calculated standard scores, the participants have higher explosive muscle force values by 2.74% relative to maximum muscle force (regardless of the arm or hand position). It is essential to point out that the highest values of maximum and explosive muscle force are achieved in the first attempt, which should be kept in mind during future testing.

Cronbach's alpha values in this study are consistent with Ivanović and Dopsaj's (2013) study, where Cronbach's alpha for F_{max} ranged from 0.964 to 0.989 for leg extensor muscles, measured by a leg extension dynamometer, and for RFD_{max} ranged from 0.739 to 0.945. An exception exists only for BBS_RFD_{max} L, where Cronbach's alpha is 0.662. Participants were tested in a seated position, where their hip angle was at 110°, knee angle 120°, and ankle angle 90°. Furthermore, Majstorović et al. (2021) measured the force of the ankle joint muscles by isometric dynamometry, where Cronbach's alpha ranged from 0.969 to 0.982 for F_{max}, while Cronbach's alpha ranged from 0.916 to 0.933 for RFD_{max}. Furthermore, ICC single measures ranged from 0.785 to 0.949, which is higher than the ICC averaged values range (0.681 – 0.971) for F_{max} and RFD_{max} values in this study. Participants were tested on a chair with knees and ankles bent so that their thighs were parallel to the ground and knees were in line with their toes. Also, Padulo et al. (2020) measured knee flexion and extension isometric peak forces, assessed with a 90° angle with a portable-with-seat dynamometer prototype (ISOM) and found high reliability (ICC 0.879–0.990). Overall, high reliability exists, but it is higher for F_{max} than RFD_{max}.

CONCLUSION

In this study, the maximum and explosive muscle force were tested in a specific arm wrestling test to determine its reliability. Very high reliability (ICC = 0.916-0.971) exists for maximum muscle force variables, measured for the left and right arm in supinatorial and neutral hand positions. Moderate and high reliability (ICC = 0.681-0.892) was found for explosive muscle force variables, measured with the left and right hand with supinatorial and neutral hand positions. Also, Cronbach's Alpha values were higher for maximum muscle force than explosive muscle force. According to the reliability results, the specific arm wrestling test has a more significant advantage in estimating maximum muscle force over explosive muscle force. Based on the established differences from 12.6% to 85.8% (Partial Eta^2 = 0.126-0.858) in the attempts to perform the test, it was concluded that the participants do not have different muscle force levels in the left and right arm. Standardized values, expressed as a percentage, show higher explosive muscle force values by 2.74% than the participants' maximum muscle force. The highest values of muscle force were achieved during the first test attempt. By looking at this information, coaches and athletes, using this specific AW test, can create a clearer picture of the athlete's current physical readiness and make appropriate decisions to guide the training process. For further and in-depth research, it is necessary to determine the metrological sensitivity and methodological validity of the given tests to determine how many attempts and which attempt should be taken as the most representative for measuring specific abilities.

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RELIABILNOST SPECIFIČNIH TESTOVA JAČINE SPORTSKOG OBARANJA RUKU

Cilj ovog rada je bio da se istraži pouzdanost specifičnog testa jačine sportskog obaranja ruku. Analizirana je maksimalna mišićna sila (F_{max}), maksimalna brzina razvoja mišićne sile (RFD_{max}) za desnu i levu ruku u određenom suprinatornom i neutralnom položaju u obaranju ruku. Uzorak varijabli obuhvatio je dve sledeće varijable: maksimalna voljna sila (F_{max}) i maksimalna voljna eksplozivna sila, tj. maksimalna brzina razvoja sile (RFD_{max}), mereno na levoj (L) i desnoj (D) ruci (musculus Biceps Brachii) za specifične položaje za sport - supinacija i neutralni položaj. Pojedinačna međutestovna pouzdanost određena je pomoću koeficijenta interklasne korelacije (ICC) i Cronbach-ove alfe na osnovu standardizovanih stavki. Statistički nivo značajnosti određen je na osnovu kriterijuma $p \leq 0.05$. Postoji vrlo visoka pouzdanost (ICC = 0,916-0,971) za varijable maksimalne mišićne sile, mereno za levu i desnu ruku sa suprinatornim i neutralnim položajima šake. Umerena i visoka pouzdanost (ICC = 0,681-0,892) pronađena je za varijable eksplozivne mišićne sile, mereno levom i desnom rukom sa suprinatornim i neutralnim položajima šake. Generalno, najviše vrednosti mišićne maksimalne i eksplozivne sile postignute su tokom prvog pokušaja testa. Uvidom u ove informacije, treneri i sportisti mogu sa pouzdanošću koristiti specifični AW test kako bi stvorili jasniju sliku o trenutnoj fizičkoj spremnosti sportiste i doneli odgovarajuće odluke za vođenje trenažnog procesa.

Ključne reči: *mišićna jačina, meterološka osetljivost, metodološka validnost*

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Research article

FITNESS PERCENTILE RANK DATA FOR FEMALE LAW ENFORCEMENT RECRUITS IN THE USA

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Abstract. *Female law enforcement personnel make up a small percentage of the population compared to males. However, female officers and recruits tend to be under-analyzed relative to their male counterparts. Female recruits also tend to be less physically fit when compared to their male peers, but the distinction of physical fitness levels within females as a specific population group has yet to be documented. This study aimed to create fitness percentile ranks for female recruits from several law enforcement agencies. Retrospective analysis on 200 females from 14 law enforcement recruit classes from agencies in three American states was conducted. Physical fitness tests were conducted prior to academy. The tests included: maximal push-ups and sit-ups in 60 s, and the 20-m multistage fitness test (assessed by number of completed shuttles and estimated maximal aerobic capacity). For all tests, if a female was below the 40th percentile specific to recruits, they were near the 50th percentile for general population norms. Female recruits should aim to be in the 50th percentile or higher of the presented percentile rankings to better their preparedness for academy. Training staff could also use the percentile rank data to profile their female recruits and highlight their strengths in muscular endurance and aerobic fitness, and areas for needed improvement. By doing so, and by also developing strength, power, and endurance, females will be more prepared to complete academy training, perform job-specific tasks, and raise the expectations and overall fitness for females as a sex group in the law enforcement community.*

Key words: *Multistage Fitness Test, Police, Push-Ups, Sit-Ups, Tactical*

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INTRODUCTION

Law enforcement officers undergo long, strenuous, and at times stressful work shifts. An officer's daily routine may consist of tasks ranging from lifting and dragging civilians or colleagues to safety, participating in a foot pursuit, or apprehending a suspect (Bissett, Bissett, & Snell, 2012; Dawes et al., 2018; Dawes et al., 2017a; Moreno et al., 2019; Orr et al., 2020a; Orr, Pope, Stierli, & Hinton, 2017; Orr et al., 2019). Due to the physically taxing responsibilities of this occupation, a great majority of law enforcement agencies throughout the USA (and the world) have a variety of fitness requirements which must typically be met before a recruit may join their respective training academy. Fitness requirements for agencies are commonly measured using a variety of tests, which may include: maximal push-ups performed in 60 seconds (s) to measure upper-body muscular endurance, maximal sit-ups performed in 60 s to measure trunk muscular endurance, and number of shuttle runs performed during the 20-meter (m) multi-stage fitness test (20MSFT) to measure aerobic fitness (Cesario et al., 2018; Dawes et al., 2019b; Dawes et al., 2017b; Lockie et al., 2019a; Lockie et al., 2020a; Lockie et al., in press; Lockie et al., 2020c; Lockie et al., 2020e; Orr et al., 2020b; Shusko et al., 2017). Furthermore, it is generally expected that law enforcement recruits obtain an adequate level of physical fitness before starting academy training (Dawes et al., 2019b; Lockie, Dawes, Orr, & Dulla, 2020b).

For most agencies, all recruits, regardless of age or sex, are expected to meet the same minimum physical fitness requirements determined by their respective agency (Bissett et al., 2012; Reaves, 2012). As there have been several discrimination lawsuits in the past, in order to ensure the largest pool of qualified candidates and avoid a disparate impact on female applicants, some police departments have developed sex-norming procedures in certain tests to control for the physiological differences between men and women (Bissett et al., 2012). Other agencies have removed initial fitness testing altogether with the express goals of recruiting more females (Silvester & Pearson, 2019). Despite sex-norming procedures in some agencies to expand the female applicant pool, it is important to clearly note that occupationally required physical tasks of female officers do not differ from those of a male. Any call for help of an ongoing crime or breach of peace is expected to be handled by whoever (male, female, younger, or older officer) is on-duty. Accordingly, it is important to review the current fitness levels of female recruits and provide some training guidelines to best prepare these individuals for success in academy and their future career (Dawes et al., 2019b).

The level of fitness for new candidates attending law enforcement academy training when considering both sexes combined tends to be similar between cohorts (Lockie et al., 2020b; Lockie et al., 2018c). However, as a majority of law enforcement recruits are male (Dawes et al., 2019b; Lockie et al., 2020a; Lockie et al., 2020b), this may not accurately depict the actual level of fitness of females. Indeed, when investigating the influence of sex on physical fitness, female recruits generally display lower strength, muscular endurance, and aerobic fitness when compared to male recruits (Cesario et al., 2018; Dawes et al., 2019b; Lockie et al., 2020a; Lockie et al., 2020b; Lockie et al., 2018b; Lockie et al., 2020c). Specifically, male recruits tend to demonstrate greater performance in both lower- and upper-body tests such as in the seated medicine ball throw, vertical jump, push-ups, and isometric grip strength when compared to female recruits (Cesario et al., 2018; Dawes et al., 2019b; Lockie et al., 2020a; Lockie et al., 2020b; Lockie et al., 2018b). Females also tend to perform significantly less 20MSFT shuttles and have lower maximal aerobic capacity ($\dot{V}O_{2max}$) values than males (Dawes et al., 2019b; Lockie et al., 2020a; Lockie et al., in press; Lockie et al., 2020c). Given that higher lean body mass has been associated with physical fitness in law enforcement populations (Dawes et al., 2016b; Lockie et al., 2020e), it is safe to assume females may be at a physical disadvantage in most assessments as males tend to have more total skeletal muscle mass (Janssen, Heymsfield, Wang, & Ross, 2000).

Nonetheless, the differences in physical fitness levels amongst female recruits is less known, with law enforcement research tending to feature low female sample sizes (Dawes et al., 2019b; Lockie et al., 2020a; Lockie et al., 2020b). The low female sample sizes that feature in research studies reflect fewer females (compared to males) serving in law enforcement careers. As of September 2019, there were 98,738 women in law enforcement compared to 645,936 men, accounting for about 15% of the entire law enforcement population (Neely, 2019). More detailed analyses of female recruits are required to characterize this group.

Therefore, this study detailed percentile ranks of female recruits' fitness test performance in the number of push-ups, sit-ups, 20MSFT shuttles completed, and estimated $\dot{V}O_{2max}$. This was done to better distinguish fitness levels for female law enforcement recruits. Retrospective analysis was conducted on pre-existing de-identified data provided by three law enforcement agencies. The data in this study was also categorized relative to general population norms (Riebe, Ehrman, Liguori, & Magal, 2018), and previous law enforcement recruit data (Dawes et al., 2019b; Lockie et al., 2019a; Shusko et al., 2017). This was done to highlight the challenges for females who may report to academy with low fitness levels. The percentile rank data composed in this research could be used to drive training practices for female candidates for a law enforcement agency, or recruits in the lead-up to academy.

METHODS

Participants

Retrospective analysis of data for female recruits from 14 law enforcement academy classes across three states in the USA was conducted. The data presented in this paper were released with consent from the law enforcement organizations in question for the purpose of conducting this research. A convenience sample of a total of 200 female law enforcement recruits (age: 27.4 ± 6.3 years; height: 1.62 ± 0.07 m; body mass: 65.6 ± 10.8 kg) were analyzed in this study. As this was a convenience sample of data provided by the agencies, the researchers had no control of the final sample size. Inclusion criteria for the participants included complete data sets. Even though previous research has shown fitness can vary between different agencies (Myers et al., 2019), this study provided a larger data sample drawn solely from female recruits. Based on the archival nature of this analysis, institutional ethics committees approved the use of pre-existing data (HSR-17-18-370, ED-19-146-STW). The study still conformed to the recommendations of the Declaration of Helsinki (World Medical Association, 1997).

Procedures

The data in this study were collected by staff working for three different law enforcement agencies. The tests that were selected for analysis in this study were consistent across the agencies and performed with the same methodology. All recruits were tested prior to their respective training academy (as an initial academy assessment) as part of normal practice. Recruits were required to complete the fitness assessments within their academy physical training for each agency, often part of larger testing batteries (Lockie et al., 2020e). The staff from each agency were all trained to conduct the tests analyzed in this study.

Push-ups

Each agency's training staff measured upper-body muscular endurance via a push-up test where recruits completed as many repetitions as possible in 60 s. Established procedures were used by all agencies (Lockie et al., 2018a; Lockie et al., 2020b). A tester placed a fist on the floor directly under the recruit's chest to ensure they descended to an appropriate depth. Although there may be some limitations with this approach, this ensured recruits descended to the required depth. All the female recruits were partnered with a female tester. On the start command, the tester began the stopwatch and the recruit flexed their elbows and lowered themselves until their chests contacted the tester's fist before they extended their elbows to return to the initial position. Recruits correctly performed as many correct push-ups as possible using this technique within the allocated time.

Sit-ups

Abdominal muscular endurance was assessed via the sit-up test where recruits completed as many repetitions as possible in 60 s. This test also used standard procedures (Lockie et al., 2018a; Lockie et al., 2020b). The recruits laid on their backs with their knees flexed to 90°, heels flat on the ground, and arms crossed over the chest. The feet were held to the ground by a tester who also counted the repetitions as they were positioned so they could view the technique and could communicate with the recruit. On the start command, recruits raised their shoulders from the ground while keeping their arms crossed over the chest and touched their elbows to their knees. The recruit then descended back down until their shoulder blades contacted the ground. Recruits completed as many correct repetitions as possible using this technique within the allocated time.

20-m Multistage Fitness Test (20MSFT)

The 20MSFT was proctored using a previously established methodology (Dawes et al., 2019b; Lockie et al., 2019a; Lockie et al., in press; Lockie et al., 2020c; Lockie et al., 2019d; Lockie et al., 2020e; Moreno et al., 2018; Orr, Ford, & Stierli, 2016). Recruits ran back and forth between two marked lines which were spaced 20 m apart. The speed of running for this test was standardized by pre-recorded auditory cues (i.e., beeps) played from an audio device. The recruits needed to reach the line on their opposite side before the auditory cues were given. Initial speed was set at 8.5 km/h and increased by 0.5 km/h after every minute. The test was terminated when the recruit was unable to reach the opposing lines twice in a row in accordance with the auditory cues. This test was scored according to the total number of shuttles completed. Using the total number of completed 20MSFT shuttles as a metric for aerobic fitness is a common approach in law enforcement research (Dawes et al., 2019b; Dawes et al., 2017b; Lockie et al., 2019a; Lockie et al., in press; Lockie et al., 2020c; Lockie et al., 2019d; Lockie et al., 2020e; Moreno et al., 2018; Orr et al., 2016). In addition to shuttle number, $\dot{V}O_{2max}$ (measured in milliliters per kg body mass per minute; ml/kg/min) was estimated for each recruit based on the table from Ramsbottom, Brewer, & Williams (1988). Estimating $\dot{V}O_{2max}$ in this manner has been done in previous law enforcement research (Lockie et al., in press; Lockie et al., 2020c).

Statistical Analysis

Data were collated for the female recruits between the different academy classes across the agencies. Microsoft Excel (Microsoft Corporation™, Redmond, Washington, USA) was used to calculate the percentile ranks (Lockie & Hernandez, 2020; Lockie et al., 2020b). The "Rank and Percentile" tool within the Data Analysis ToolPak was used to calculate the percentile rankings for each fitness assessment in bands of 10 ranks (e.g. 90-100, 80-89, 70-79, etc.). Comparisons were also made to general population normative data (Riebe et al., 2018), and to studies that have measured the physical fitness performance of recruits who graduated or separated academy (Dawes et al., 2019b; Lockie et al., 2019a; Shusko et al., 2017).

RESULTS

The percentile rankings are shown in Table 1. When compared to normative data from Riebe et al. (2018), female recruits tended to score superior or similar to the general population norms for females in push-ups and sit-ups, but tended to perform poorer in aerobic capacity. Firstly, the number of push-ups ranged from 2 to 56 repetitions, with the mean number of push-ups performed by these female recruits (27 repetitions) falling in the good-to-excellent range relative to the general population (Riebe et al., 2018). Further, the mean push-up repetition value in this study was less than the mean number performed by recruits who did not successfully graduate from academy (~32-40 repetitions), which was documented in previous research (Dawes et al., 2019b; Lockie et al., 2019a; Shusko et al., 2017). Relative to the female recruits presented in this analysis, the mean number of push-ups performed by recruits who failed academy fell anywhere within the 70th to 87th percentile rank.

The number of sit-ups performed ranged from 5 to 58 repetitions, with the mean number of sit-ups performed by these female recruits (32 repetitions) being similar to the mean number performed by recruits who failed to graduate from academy (~32-33 repetitions) (Lockie et al., 2019a; Shusko et al., 2017). The mean number of sit-ups performed by recruits who failed academy fell anywhere into the 40th to 89th percentile rank. General population data for the sit-up was not available in Riebe et al. (2018).

Table 1 Percentile rankings for push-ups (n = 196), sit-ups (n = 197), 20MSFT shuttles (n = 200), and $\dot{V}O_{2max}$ (n = 200) from female recruit data. 'Recruit No.' refers to the number of recruits in each percentile rank.

Percentile Rank	Push-up Range	Recruit No.	Sit-up Range	Recruit No.	Shuttle Range	Recruit No.	$\dot{V}O_{2max}$ Range	Recruit No.
90-100	43-56	18	44-58	18	68-100	20	41.1-50.2	19
80-89	36-42	21	39-43	21	60-67	20	37.7-41	21
70-79	32-35	20	37-38	13	54-59	17	35.5-37.8	20
60-69	30-31	16	35-36	22	47-53	22	34-35.4	16
50-59	27-29	23	33-34	22	43-46	20	32.8-34.1	24
40-49	25-26	19	31-32	20	39-42	21	31.2-32.7	17
30-39	22-24	19	29-30	14	38	10	30.6-31.1	14
20-29	18-21	21	27-28	23	35-37	24	29.1-30.5	23
10-19	16-17	17	24-26	22	30-34	22	27.5-29	22
<10	2-14	22	5-23	22	8-28	24	26.8-27.4	27

The number of 20MSFT shuttles completed by these female recruits ranged from 8 to 100, with the mean number shuttles completed equaling 46 shuttles. When compared to other recruits who did not complete their academy training, these female recruits performed better than separated recruits from California (40 shuttles) (Lockie et al., 2019a), but worse than other separated recruits from Colorado (49 shuttles) (Dawes et al., 2019b). The recruits from previous studies who did not successfully graduate from academy fell in the 40th to 65th percentile rank.

Lastly, the recruit's $\dot{V}O_{2max}$ ranged from 26.8 ml/kg/min to 50.2 ml/kg/min, with a mean score of 33.3 ml/kg/min. Depending on the age of the recruit, this mean $\dot{V}O_{2max}$ value was in the poor-to-good range relative to the general population (i.e., if a 20-29 year old younger recruit had this $\dot{V}O_{2max}$, they would be classified as poor; a 30-49 year old would be classified as good) (Riebe et al., 2018). This mean $\dot{V}O_{2max}$ was below the mean $\dot{V}O_{2max}$ reported from recruits who did not graduate from academy in Massachusetts (39.06 ml/kg/min) (Shusko et al., 2017). The mean for the separated recruits from Shusko et al. (2017) would have positioned them near the 85th percentile rank of the female recruits in this analysis.

DISCUSSION

This study presented percentile ranks for upper-body (push-ups) and abdominal (sit-ups) muscular endurance, and aerobic fitness (20MSFT shuttles and estimated $\dot{V}O_{2max}$) specific to female recruits. Females were the focus of this research as they tend to comprise a much percentage of staff within a law enforcement agency (Neely, 2019), and also have low sample sizes in the research (Dawes et al., 2019b; Lockie et al., 2020a; Lockie et al., 2020b). Although this study analyzed general fitness tests and not job-specific tasks, these assessments are used to track fitness in law enforcement academies (Cocke, Dawes, & Orr, 2016), ensure sufficient fitness to minimize the risk of injury when undergoing academy training (Lockie et al., 2019a; Tomes, Schram, Pope, & Orr, 2020), and also underpin the physical qualities needed for job-specific tasks (Beck et al., 2015; Dawes et al., 2017a; Lockie et al., 2018a). Indeed, the push-up, sit-up, and 20MSFT are commonly used to determine initial hiring, gauge progress, and provide scoring for performance in physical training (Cesario et al., 2018; Dawes et al., 2019b; Lockie et al., 2019a; Lockie et al., 2018a; Lockie et al., in press; Lockie et al., 2020b; Lockie et al., 2020c; Shusko et al., 2017). As will be discussed, the results from this study further highlighted the importance of specific physical fitness characteristics needed in female recruits.

The push-up is one of the most well-known exercises used in tactical populations. It is employed as a physical conditioning tool within tactical populations to help determine improvement in physical fitness after a new or modified physical conditioning program (Dawes et al., 2016a). Not only is the push-up test easy to administer due to its ability to be performed anywhere on a flat surface (e.g., grass, concrete, dirt), but evidence has also shown baseline push-ups when starting academy training as predictor of successful academy graduation (Dawes et al., 2019b; Shusko et al., 2017). Accordingly, the push-up test a very popular measure of physical fitness in both general and tactical population fitness assessments to measure and assess muscular endurance (Dawes et al., 2016a). Sit-ups have also been a staple exercise in tactical populations due to their commonality in being easy to administer and perform by the individuals being tested. Since research has shown push-ups and sit-ups measure different physical qualities (upper-body pushing vs. abdominal endurance) (Cesario et al., 2018), as well as also being related to multiple occupational tasks (Beck et al., 2015; Lockie et al., 2018a), these two exercises should be fundamental exercises included in a female recruit's strength and conditioning program to better optimize their overall physical fitness.

Aerobic fitness is also a crucial physical component for female recruits. Lesser performance in the 2.4-km (1.5-mile) run or 20MSFT has been associated with academy failure (Dawes et al., 2019b; Lockie et al., 2019a; Lockie et al., 2020a; Shusko et al., 2017; Tomes, Sawyer, Orr, & Schram, 2020), while higher aerobic capacities are significant predictors of occupational performance (Beck et al., 2015; Dawes et al., 2017a; Lockie et al., 2018a). Although academy training focuses on the betterment of their recruits' aerobic capacity, females should still be implementing some aerobic endurance training prior to academy to maintain (or enhance) their aerobic capacity. This is especially notable given the importance of aerobic fitness in law enforcement job tasks (Beck et al., 2015; Dawes et al., 2017a; Lockie et al., 2018a), and how generally female recruits may have lower aerobic capacity compared to males (Dawes et al., 2019b; Lockie et al., 2020a; Lockie et al., in press; Lockie et al., 2020c).

For all these tests, if a female was below the 40th percentile in this sample of recruits, they were generally considered to be near the 50th percentile for general population norms (Riebe et al., 2018). However, it should be noted, this may not be an ideal ranking for female recruits because of the relationships between fitness and performance in academy (Dawes et al., 2019b; Lockie et al., 2019a; Lockie et al., 2020a; Shusko et al., 2017) and within job-specific tasks (Beck et al., 2015; Dawes et al., 2017a; Lockie et al., 2018a). Female recruits should ideally aim to be in the 50th percentile or higher of these presented percentile rankings in this recruit-specific population to better their preparedness for law enforcement academy training. Further to this, since the physical characteristics and performance of both sexes may decline with age in incumbent officers (Dawes et al., 2017b; Lockie, Dawes, Kornhauser, & Holmes, 2019c; Lockie et al., 2019e; Orr, Dawes, Pope, & Terry, 2018a), it is even more crucial for female recruits in the older age ranges (35 years of age or more) to arrive at academy at a higher level of physical preparedness relative to their respective general population norms. This is because they are already inclined to be at an initial physiological disadvantage compared to males their age (Dawes et al., 2017b; Lockie et al., 2019a; Lockie et al., 2020a; Lockie et al., 2019c).

There are study limitations that should be noted. This study incorporated female recruits from three different law enforcement agencies. As previously stated, fitness can vary across different agencies (Myers et al., 2019), so future investigations should incorporate more agencies to increase the sample size even further. The testing and environmental conditions may have varied across the different classes in each agency (Lockie et al., 2020b), although this limitation is almost unavoidable given the type of investigation conducted. Only three fitness assessments (push-ups, sit-ups, and the 20MSFT) were incorporated into this study. In addition to muscular endurance and aerobic capacity, some other important fitness qualities for law enforcement personnel include maximal strength, upper- and lower-body power, and anaerobic endurance (Beck et al., 2015; Dawes et al., 2017a; Lockie et al., 2018a; Lockie et al., 2020d; Lockie et al., 2021b; Orr, Caust, Hinton, & Pope, 2018b). Future research should categorize these qualities for female recruits. This could include tests such as grip strength, isometric leg/back dynamometer, and hexagonal bar deadlift to measure strength (Dawes et al., 2019a; Dawes et al., 2017b; Lockie, Balfany, Denamur, & Moreno, 2019b; Lockie et al., 2020d); the vertical jump, standing broad jump, and medicine ball throw to measure power (Dawes et al., 2019a; Dawes et al., 2019b; Lockie et al., 2019a; Lockie et al., 2021a; Lockie et al., 2020a; Lockie et al., 2018b; Lockie et al., 2021b; Lockie et al., 2020e; Moreno et al., 2019); and a 300-m run (or something similar) to assess anaerobic capacity (Cocke et al., 2016; Moreno et al., 2018; Orr et al., 2018a).

CONCLUSION

In conclusion, it should be strongly noted that an individual's sex should not be considered a limitation in the law enforcement profession. While required occupational tasks are the same for both sexes, limitations in fitness (which can also be applied to men) could be the more challenging aspect. With the percentile ranks shown in this paper, law enforcement academy training staff can use this data to profile their female recruits and highlight their strengths in muscular endurance and aerobic fitness, and areas for needed improvement. For females considering law enforcement as a potential career, they should strive to better their aerobic capacity to potentially match normative $\dot{V}O_{2max}$ values in females from this recruit-specific population. By doing so, and by also further developing strength, power, and endurance, females will be more prepared to complete academy training, perform job-specific tasks, and raise the overall fitness for females in the law enforcement community.

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RANGIRANJE FIZIČKE SPREMNOSTI ŽENA REGRUTA U POLICIJSKIM SNAGAMA U SJEDINJENIM DRŽAVAMA

Žene u policijskim snagama čine mali procenat stanovništva u poređenju sa muškarcima. Međutim, žene policajke i regruti su nedovoljno analizirane u odnosu na svoje kolege muškog pola. Žene regruti takođe su često manje fizički sposobne u poređenju sa svojim vršnjacima, ali razlika u stepenu fizičke spremnosti žena kao posebne grupe stanovništva tek treba da se dokumentuje. Ova studija je imala za cilj stvaranje rangova fizičke spremnosti za žene regrute iz nekoliko agencija policijske službe. Sprovedena je retrospektivna analiza na uzorku 200 žena iz 14 regrutnih odeljenja iz agencija u tri američke države. Testovi fizičke spremnosti sprovedeni su pre neko štu su ispitanice pristupile policijskoj akademiji. Testovi su uključivali: maksimalan broj sklekova i trbušnjake za 60 sekundi, kao i višestepeni fitnes test na 20 metaraa (procenjen prema broju završenih shuttle run sprintova i procenjenim maksimalnim aerobnim kapacitetom). Za sve testove, ako je žena bila ispod 40. podeoka specifičnog za regrute, bila je blizu 50. podeoka za opšte populacione norme. Žene regruti trebalo bi da teže u najmanju ruku ka 50. podeoku kako bi poboljšale svoju pripremljenost za akademiju. Osoblje za obuku bi takođe moglo da koristi podatke o rangu za profilisanje svojih regruta, kako bi istakli njihove prednosti u pogledu mišićne izdržljivosti i aerobne kondicije, kao i oblasti na kojima bi trebalo dodatno poraditi. Na taj način, i razvijanjem snage, moći i izdržljivosti, žene će biti spremnije da završe akademsku obuku, obavljaju zadatke specifične za posao i povećaju očekivanja i ukupnu sposobnost žena kao rodne grupe u policijskim snagama.

Ključne reči: *višestepeni fitness test, policijske snage, sklekovi, vežbe za stomačne mišiće, taktički trening*

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