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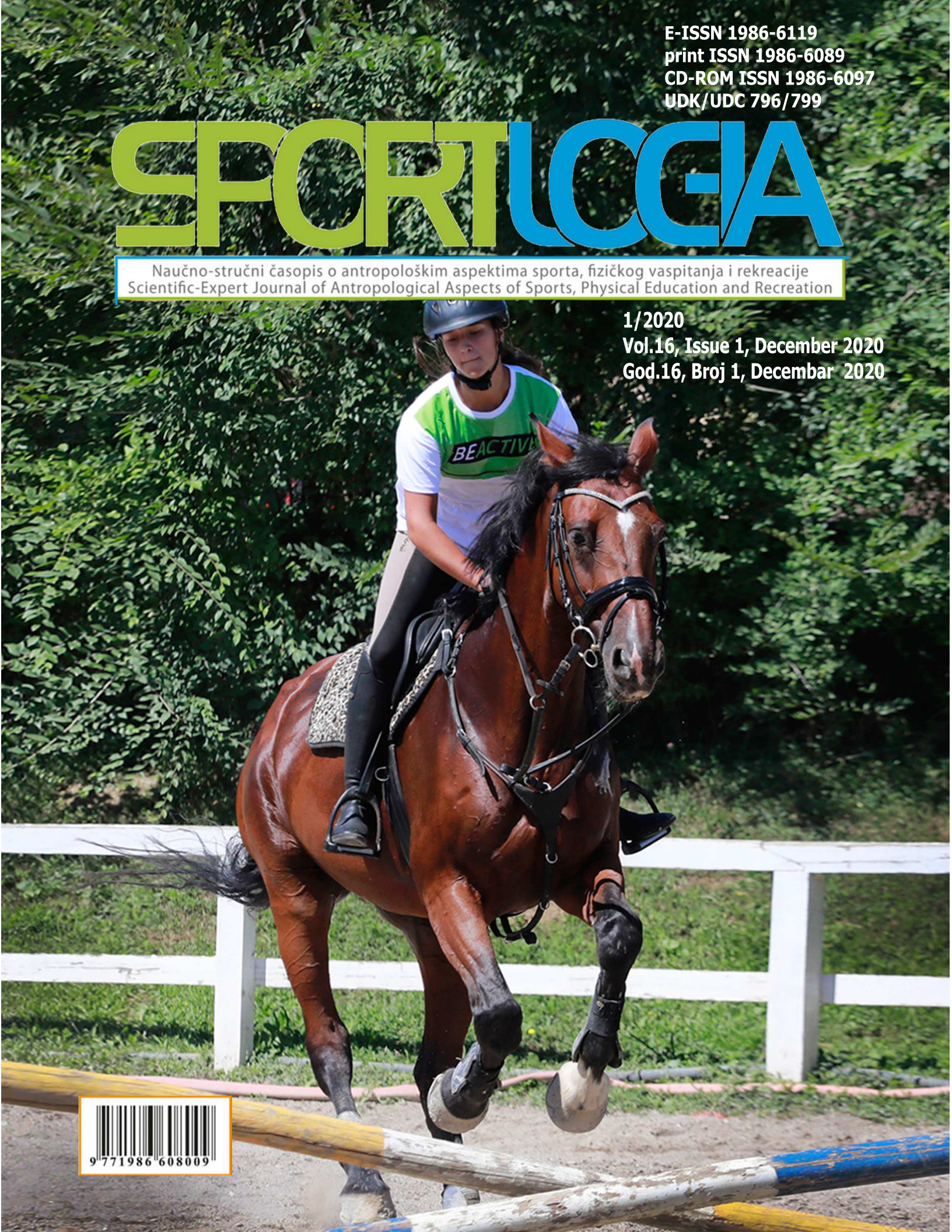

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PARAMETERS OF FUNCTIONAL ABILITIES IN RUNNING – RESEARCH REVIEW

PARAMETRI FUNKCIONALNIH SPOSOBNOSTI U TRČANJU – PREGLEDNO ISTRAŽIVANJE

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ABSTRACT

Running as an athletic discipline requires a high level of endurance and speed endurance, which is directly related to the cardiovascular and respiratory systems, ie the ability of an athlete's body to withstand loads, and the following are listed as relevant factors for running success: anaerobic strength and maximum O_2 consumption, lactic acid concentration and oxygen deficiency, ability to withstand stress, high ability to concentrate and its retention over longer periods of time. There is a lot of research that has studied the parameters of functional abilities in an attempt to find the most effective way to improve them, and since there are many similar and different data on this topic, this paper has been done to classify the available papsers by domestic and foreign authors which would lead to conclusions applicable both in practice and for further research

For the purposes of this research, original scientific papers have been analyzed that dealt with functional abilities as success factors in short, middle and long distance running and the impact of training on functional abilities, found in electronic databases - Medline, PubMed, Researchgate, Web of Science and Google Scholar. The research used in this review monitored transversely the values of submaximal and maximal oxygen consumption, energy systems, heart rate values, pulmonary ventilation, blood lactate concentration, as well as their changes after longitudinal implementation of experimental protocols and training processes. Since the collected research had too few respondents from different populations with a small number of elite runners, and they did not have enough information about many years of experience, level of sports form, race categories, and descriptions of training and methods, obtaining empirical information based on evidence was limited, as well as reaching valid conclusions. Accordingly, there is a need for a more systematic approach to research and implementation of complex studies with a sufficient number of runners of all ages, both sexes of the elite level, and cooperation of academic

researchers, clubs and athletes to enable studies that would provide significant statistics, analysis and interpretation. The results identified in this review provide a starting point for future research that identifies and quantifies predictors of functional performance as factors of short, middle, and long distance running success.

Keywords: maximum oxygen consumption, lactate concentration, short distances, middle distances, long distances, training process

INTRODUCTION

Relevant factors stated for success in running on middle distances are: anaerobic strength and maximum VO_2, lactic acid concentration and lack of oxygen, ability to withstand stress, high ability to concentrate and its retention over longer period of time, and as maximum consumption oxygen (VO2max), which an athlete can achieve is not the only main determinant at endurance effort, but a significant role is played by a possible level at which maximum aerobic capacity can be used, many studies also state that an untrained beginner can raise his VO_2max 15-20% in just 12-16 weeks of regular and proper training (Frajtnic, 2012). Aerobic endurance can be improved by increasing oxygen uptake by increasing the ability to assimilate, transfer and use oxygen and by raising the anaerobic threshold to be able to run at higher speeds without entering the anaerobic zone, but it should be borne in mind that the role of aerobic and anaerobic capacity and anaerobic energy sources in running depends on the intensity and duration of running (Skof, Kropej & Milic, 2002), and the quality of performance and success depend on the amount and structure of training load in a certain period of time.

Improving oxygen uptake by increasing the ability to assimilate, transfer and use oxygen is best achieved by a continuous load method, while raising the anaerobic threshold resulting in the ability to run at higher speeds without entering the anaerobic zone is best achieved by a repetitive load method (Coh, 1992). Also, different body structures are essential for young athletes during selection(Malousaris, Bergeles, Barzouka, Bayios, Nassis, & Koskolou, 2008), which are crucial for improving skills in many sports (Carter & Heath, 1990), and to assess the structure of

the whole body and its individual components it is necessary to identify anthropometric characteristics (McArdle & Katch, 1991). In boys at puberty there are rapid changes in the body, along with the accelerated growth of the skeleton muscle mass increases, which is the main reason for increasing maximum oxygen intake and improving endurance (which was low in the initiation phase) and athletic achievement (Idrizovic, 2013).

Anaerobic endurance research has also been addressed (Bowerman et al. 1999), as well as statements that anaerobic endurance can also be improved in two ways: by improving the ability to tolerate high levels of lactic acid which will allow continued activity and training of the neuromuscular system at a pace of racing and by improving anaerobic capacity of cells by increasing the amount of energy stored in the ATP of muscle cells. Aerobic endurance in one of its phases reaches stagnation, although the training process is carried out, so the goal in this phase (the phase of shaping athletes) should be - by applying endurance training to increase aerobic and anaerobic endurance, ie. bring any increase in endurance, which occurred during prepuberty, to a higher level (Bompa, 2006). Also, it was found that (Rotstein, Dofan, Bar & Tenenbaum, 1986) nine-week interval training, in athletes, had a positive effect on anaerobic threshold, anaerobic capacity and aerobic power and led to an increase in anaerobic capacity (VO_2max). It was shown that two types of interval training - focused on lactate and ventilatory threshold led to an increase in VO_2max by 5% and 6%, in lactate threshold by 19.4% and 22.4% and ventilatory threshold by 19.5% and 18.5% and 18.5%, respectively (Burke, 1998).

Several previous studies (Morgan, Baldini, Martin, & Kohrt, 1989; Powers, Dodd, Deason, Byrd, & McKnight, 1983) have shown that maximal oxygen consumption (VO_2max), running speed at the lactate limit, and running economy at higher speeds are significantly related to success in running. Results in long-term aerobic activities have high correlations with the intensity of physical activity at the anaerobic threshold (Costill et al., 1985; Farrell et al., 1979; Rhodes & McKenzie, 1984) and are an indicator of individual aerobic capacity (Peronet et al., 1987; Tanaka, 1983). At a load of more than 60 to 90 seconds, energy needs are covered in a

situation where the work is increasingly aerobic, noting that at aerobic loads of constant intensity during the total duration of the load lactate may remain at normal level or slightly above normal (Malacko & Radjo, 2004). Lacour, Bouvat & Barthélémy (1990) investigated blood lactate concentrations as indicators of anaerobic energy consumption during 400m running. Ohkuwa, Kato, Katsumata, Nakao & Miyamura (1984) investigated blood lactates and glycerin after running at 400m and 3000m (in sprinters and long-distance runners), and concluded that peak blood lactate obtained after running at 400m could be used as an indicator of anaerobic performance in long-distance runners and untrained groups, but not in sprinters.

It is known that an increasing number of authors emphasize the importance of developing energy capacity in athletes regardless of the needs of the parent sport or the requirements of sports discipline (Bompa, 1999; Holmann & Hettinger, 2000). The Maximal Lactate Steady State (MLSS) or anaerobic threshold (second ventilation threshold) is defined by the intensity of work at which it is still possible to achieve a stable state of VO_2 and lactic acid in blood, ie. a balance can be established between the process of accumulation and degradation of lactic acid (Barstow et al., 1993). The anaerobic threshold is reached at an intensity of about 80 - 90% VO_2max (in non-athletes at 65 - 70% VO_2max, and in trained people even at 95% VO_2max, depending on the training cycle - preparatory, pre-competition or competition), with a concentration of lactic acid in blood of about 3-5 mmol/l (Viru, 1995). Sports activities of relatively short duration and high intensity, for the realization of which there is essentially high level of anaerobic endurance and speed and strength endurance, draw most of their energy from anaerobic reserves, ie. from anaerobic energy capacities (Vucetic & Sentija, 2005).

As it can be seen, there is a lot of research that has studied the parameters of functional abilities in an attempt to find the most effective way to improve them, which would lead to improved results in running, and since there are many similar and different data on this topic, this paper was done with the aim of classifying the available papers of domestic and foreign authors, which would lead to conclusions applicable both in practice and for further research.

METHODOLOGY

For the purposes of this research and finding appropriate original scientific papers in athletics and the importance of functional abilities to achieve results in running, and through keywords: training process in running, anaerobic trace, lactate concentration, maximum oxygen consumption, electronic databases were used - Medline, PubMed, Researchgate, Web of Science and Google Scholar. After removing irrelevant articles, the remaining articles were compiled and the full text of each was read to assess eligibility for inclusion. Eligibility criteria were created for the independent presentation of titles and abstracts found during the literature search and included topics related to short, middle and long distance running, functional abilities, improvement of VO_2max, lactate concentration. Based on the criteria and results of the research, the collected data are classified into four tables - according to research that examined functional abilities of short distance, middle distance and long distance runners, while the last table contains an overview of research that addressed the impact of training on functional abilities of runners.

RESULTS

Table 1. *Functional abilities researched in short-distance runners*

Author	Sample of respondents	Tests	Results
Kurelic et al. (1975)	34	– running at 100m, 1500m – heart rate and – vital capacity of lungs	– improved result at 1500m, – decrease in heart rate
Roberts et al. (1979)	sprinters and middle distance runners	– maximum aerobic power, – anaerobic threshold	– middle distance runners have a higher VO_2max and a higher anaerobic threshold
Nummela & Rusko (1995)	8 (short distance runners) 6 (middle distance runners)	– O_2 consumption after exercise (EPOC)	– relative contribution of anaerobic energy yield ↓ from 80% to 60% during the first 15 seconds in both groups – No correlation was found between O_2 deficiency and EPOC
Spencer, Gastin, & Payne (1996)	4 (short distance runners) 5 (middle distance runners)	– assessment of aerobic and anaerobic systems by AOD method	– There is no difference in AOD – In short distance runners ↑ VO_2max at 400 meters compared to middle distance runners during the 800m and 1500m races
Spencer & Gastin (2001)	20 (runners - 3 specialized for 200 m, 6 for 400 m, 5 for 800 m, 6 for 1500)	– relative contribution of aerobic and anaerobic energy system calculated by AOD method	– ↑ AOD with load duration during 200m, 400m and 800m running
Nagasawa (2013)	5 (middle distance runners) 5 (short distance runners) 6 (control group)	– rate of muscle reoxygenation (T1/2 StO_2) – maximum oxygen consumption (VO_2max)	– T1/2 StO_2 had a significant positive correlation with VO2max

It is assumed that the correlation of functional abilities (VO_2max, heart rate, lung capacity, oxygen deficit) is highly correlated with running at middle distances and depends to a large extent on their values. And as can be seen in Table 1, the authors dealt with the problem of changes in functional abilities during and after appropriate loads in short-distance runners, but also in middle-distance runners as a control group. Kurelic et al. (1975) were among the first performing researches on the connection between running middle distances and functional abilities, where on the sample of 34 respondents aged 22 years +/-6 months he came to the conclusion that the results of running at 1500m are significantly related to heart rate as one type of functional abilities. By investigating the differences in the value of the anaerobic threshold and the maximum oxygen consumption (VO_2max) in short-distance runners and middle-distance runners, Roberts et al. (1979), found that middle distance runners have a higher VO_2max and a higher anaerobic threshold. In a sample of 8 male short-distance runners and 6 male middle-distance runners, Nummela & Rusko (1995) analyzed the values of oxygen deficiency (AOD), excessive oxygen consumption, and lactate concentration after exhaustive work (up to maximum). The results showed that the relative contribution of the anaerobic energy source decreased from 80% to 60% during the first 15 seconds of exhaustive work in both groups of respondents. Also, in both groups of respondents, the maximum oxygen consumption (VO_2max) reached its peak in the interval from 25 to 40 seconds of exhaustive work in both groups. However, the relative contribution of the aerobic energy source was significantly higher in the group of middle distance runners (54-63%) compared to short distance runners (43-47%) and a statistically significant difference was observed ($p < 0.05$). Comparing VO_2max in different disciplines, Spencer, Gasin, & Payne (1996) tested 4 short distance runners and 5 middle distance runners. They came to the results that no significant differences in AOD were found between the respondents. They also came to the conclusion that short distance runners achieved in the 400m test (98% VO_2max) while middle distance runners achieved in the 800m and 1500m running (90% and 94% VO_2max). The relative contribution of the aerobic and

anaerobic energy system calculated by the accumulated oxygen deficiency (AOD) method was analyzed by Spencer & Gastin (2001) on a sample of 20 athletes grouped by running disciplines (200m N=3, 400m N=6, 800m N=5, 1500m N=6). The size of the oxygen deficit (AOD) increased with the duration of the load during the run at 200, 400 and 800 m (30.4 +/- 2.3, 41.3 +/- 1.0 and 48.1 +/- 4.5 ml/kg), but no further increase in running at 1500 m (47.1 +/- 3.8 ml/kg) was observed. The transition to consumption by a predominantly aerobic energy system occurred between 15 and 30 seconds when running at 400, 800 and 1500 m. In a sample of two groups, an experimental group consisting of 5 male long distance runners and 5 male short distance runners, and a control group consisting of 6 male subjects, Nagasawa (2013) analyzed oxygen saturation in muscle tissue (StO_2) in muscles vastus lateralis, the rate of muscle reoxygenation after exercise estimated at half the time required for StO_2 recovery (T1/2 StO_2) and aerobic capacity estimated by measuring maximum oxygen consumption (VO_2max). The rate of reoxygenation (T1/2 StO_2) in middle distance runners (25.0 ± 4.5 seconds) was significantly longer than in the control group (1515.9 ± 1.6 seconds; $p < 0.01$) and in short distance runners (18.0 ± 4.6 seconds; $p < 0.05$). In all respondents (middle distance runners, short distance runners and control group), T1/2 StO_2 had a significant positive correlation with VO_2max ($r = 0.75$; $p < 0.01$) and was longer in subjects with higher VO_2max. The primary limitations of most current literature investigating the impact of different training programs on sprint performance are that they usually involve only one training modality per research (i.e., do not investigate longitudinal effects of periodization) or per group of athletes, (Cormie et al. 2010) or are not based on elite sprinters (Bolger, Lyons, Harrison, & Kenny, 2015).

Table 2. *Functional abilities researched in middle distance runners*

Author	Sample of respondents	Tests	Results
Krsmanovic (1987)	64	– functional abilities – 1500m	– statistically significant correlation of running at 1500 m with functional abilities
Vuksanovic (1999)	431	– motor skills – functional abilities	– positive influence of MS and FS on the results of running at 1000m
Stoiljkovic et al. (2004)	32	– Ventilation threshold (VT) measurement and VO_2max	– oxygen intake at ventilation threshold and VO_2max increased significantly
Gasiin, Costill, Lawson, Krzeminski, & McConell (1995)	9 (VO_2max = 57 +/- 3) 12 (VO_2max = 55 +/- 3)	– supramaximal effort by the AOD method	– AOD is a reliable method of assessment of VO_2max
Mayhew (1977)	9	– VO_2max – energy consumption	– oxygen consumption and running speed are correlated – calorie consumption is independent of running speed
Pate, Macera, Bailey, Bartoli, & Powell (1992)	188 (119 men, 69 women)	– heart rate and ventilation – VO_2max	– VO_2max, HR6 and VE6 are significantly positively correlated with VO_2-6
Fletcher, Esau, & Macintosh (2009)	16	– VO_2max	– no difference in oxygen consumption in relation to speed was found – ↑ caloric consumption with speed
Allen, Seals, Hurley, Ehsani, & Hagberg (1985)	16	– VO_2max – lactate concentration	– older athletes had 9% ↓ VO_2max than younger ones – older athletes achieved 2.5 m/mol blood lactate levels at a higher percentage of their VO_2max
Brisswalter & Legros (1994)	10	– running energy costs (C), ventilation (VE), respiratory frequency (RF), heart rate (HR), lactate concentration (La) and steps rate (SR)	– no significant differences were found between tests in C, VE, RF, HR, SR – significant everyday differences were found in La
Daniels & Oldrige (1971)	14 (Boys aged 10-15 years)	– submaximal and maximal $\dot{V}O_2$	– over a 12-month period ↑ $\dot{V}O_2max$
Daniels, Oldridge, Nagle, & White (1978)	20 (10-18 years of age)	– submaximal and maximal $\dot{V}O_2$	– VO_2max is correlated with body weight – duration of training contributes to change of the submaximal VO_2
Svedenhag & Sjödin (1984)	27 (middle and long distance runners) 2 (400m runners)	– VO_2max – lactate concentration	– running speed corresponding to a blood lactate concentration of 4 mmol/l differed significantly between groups – blood lactate concentration after the test ($\dot{V}O_2max$ test) was lower in long distance runners
Helgerud (1994)	6 men 6 women	– oxygen consumption during running (CR) – VO_2max	– VO_2 ml · kg – 0.75 · min – 1 was significantly higher in men than in women
Saltin et al. (1995)	3 (Kenyan runners) 3 (Scandinavian runners)	– VO_2max	– the best Scandinavian runners did not differ significantly from the Kenyan runners in VO_2max, but none of the Scandinavians achieved such high individual values as were observed in some Kenyan runners
Duffield, Dawson, & Goodman (2005)	10 (3000m runners - 8 men, 2 women) 14 (1500m runners - 10 men, 4 women)	– oxygen intake, – blood lactate concentrations	– relative contribution of aerobic energy system for 3000 m was higher in women – concentration of lactate in the blood did not differ in relation to gender and event
McConnell & Clark	10	– VO_2max	– there were no significant differences in

(1988)			maximum oxygen uptake (VO_2max) between protocols
Lourenço, Barreto Martins, Tessutti, Brenzikofer, & Macedo (2011)	11	– VO_2max – Ventilation threshold (VT) and – respiratory compensation (RCP)	– no significant differences were found in any of the analyzed parameters, including VT, RCP and VO_2max
Foster, Costill, Daniels, & Fink (1978)	26	– succinate dehydrogenase (SDH) – VO_2max	– a small connection was established between SDH and VO_2max

To examine the correlation between functional abilities and running at 1500m, Krsmanovic (1987) tested 64 subjects aged 22 years +/- 6 months and concluded that there was a statistically significant correlation between the results of running at 1500 m and functional abilities (cardiovascular system). On a sample of 431 respondents aged 18 years +/- 6 months, Vuksanovic (1999) concluded that functional abilities have a significant impact on the results of running at 1000m. Stoiljkovic et al. (2004) measured the ventilation threshold (VT) and VO_2max in 32 subjects (22.3 +/- 2.5 years) and found that the oxygen intake at the ventilation threshold increased between the initial and final testing measures (34.8 ± 6 , 3 mlO2/kg/min begining, 41.3 ± 6.2 mlO2/kg/min end) and VO_2max (52.1 ± 5.9 mlO2/kg/min beginning, 57.1 ± 5.3 mlO2/kg/min end). Assessment of the aerobic and anaerobic system by the method of accumulated oxygen deficiency AOD (Medbo et al. 1988) was performed by Gassin et al. (1995) who tested 21 subjects with VO_2max ranging from 55 +/- 3 to 57 +/- 3 at supramaximal effort by the AOD method. After the analysis, they came to the conclusion that this method is quite reliable in assessing anaerobic capacity. To determine the correlation between oxygen consumption and running speed, Mayhew et al. (1977) tested 9 male subjects, middle distance runners. They obtained results with a high correlation between oxygen consumption and running speed (r = 0,917). Pate et al. (1992) in a sample of 188 subjects (119 men and 69 women) examined the correlation between VO_2max, heart rate (HR6) and ventilation capacity (VE6) with oxygen consumption at 6 mph running (VO2-6). Correlation analysis revealed that VO_2max, HR6 and VE6 were significantly positively correlated with VO2-6 ($p < 0,001$). By conducting a running test for 5 minutes at speeds of 75%, 85% and 95% of the lactate

threshold, Fletcher et al. (2009) in a sample of 16 middle-distance runners examined the average oxygen consumption when running for 5 minutes at speeds corresponding to 75%, 85%, and 95% of the speed at the lactate threshold with a 5-minute break between phases. The results showed that the average oxygen consumption ranged from 221, 217 and 221 ml/kg and that there was no difference in oxygen consumption in relation to running speed ($p = 0.657$). VO2max and lactate levels in younger and older athletes were addressed by Allen et al. (1985). They tested the maximum oxygen consumption and lactate level in 8 male middle distance runners aged 56 +/- 5 years and 8 male middle distance runners aged 25 +/- 3 years. The obtained results showed that older athletes had lower VO_2max by 9% ($p < 0.05$), but had lower blood lactate levels at a higher percentage of their VO2max, which indicated that they could work closer to their VO_2max during the race. Brisswalter & Legros (1994) analyzed the energy costs of running (C), ventilation (VE), respiratory frequency (RF), heart rate (HR), lactate concentration (La) and steps rate (SR) in a sample of men and female middle distance runner at the usual pace of training on a treadmill -75% VO_2max at speed (15.8 +/- .02 km.h-1). They concluded that there was no significant difference between tests C, VE, RF, HR and SR between respondents in relation to gender, while only a difference was shown in test (La) $p < 0.025$. Daniels & Oldridge (1971) monitored the increase in submaximal and maximal VO_2 from exhaled air samples during a 22-month run during a treadmill test, on a sample of 14 boys aged 10-15 years. They proved that a certain period of growing up led to an increase in submaximal VO_2 from 2331 ml to 2839 ml, while there was no increase in maximum VO_2. In a langitudinal study that lasted 6 years, Daniels et al. (1978), analyzed the correlation between submaximal and maximal VO_2 on a sample of 20 male subjects aged 10–18 years. Submaximal VO_2 was measured during the last 2 minutes of a 6-minute run at a speed of 202 m/min, and maximum VO_2 was measured during 5-8 minutes in the test performed to the maximum. VO_2max ranged from 1933 ml/min for 10-year-olds to 4082 for 18-year-olds. They concluded that in all longitudinal comparisons, maximum VO_2 changes with weight change, that is, that maximum VO_2 does not increase faster than the body weight

of active boys aged 10 to 18 years. On a sample of 29 middle and long distance runners who were divided into 6 groups (groups of runners from 400 m to marathon), Svedenhag & Sjödin (1984) analyzed VO_2max and blood lactate concentration. Maximum oxygen consumption was analyzed based on running tests at speeds of 15 km/h and 20 km/h, and at these speeds it did not differ significantly between groups. Running speed corresponding to a blood lactate concentration of 4 mmol/l differed significantly between the groups with the highest value (5.61 m/s) in the 5000 to 10000 m group, while the blood lactate concentration after the tests was lower in long distance runners. Helgerud (1994) tested the maximum oxygen consumption VO_2max and lactate threshold in 6 men and 6 women aged 20 to 30 years and concluded that men showed about 10% higher VO_2max, but no difference was found in relation to the level of lactate threshold between men and a women. By investigating the maximum oxygen consumption VO_2max at different altitudes, on a sample of Kenyan and Scandinavian boys aged 14.2 +/- 0.2 years, Saltin et al. (1995) made a number of conclusions. At higher altitudes, inactive Kenyan boys had a maximum oxygen intake (VO_2max) of 47 (44-51) ml/kg/min, while boys of similar age who regularly walked or ran but did not train for the competition reached VO_2max above 62 (58 -71) ml/kg/min. Kenyan runners in active training had VO_2max 68 +/- 1,4 ml/kg/min at higher altitudes, while they achieved VO_2max 79,9 +/- 1,4 ml/kg/min at sea level. It was also observed that some Kenyan boys reached a VO_2max of 85 ml/kg/min at sea level. The best Scandinavian runners did not differ significantly from the Kenyan runners in VO_2max both at higher altitudes and at sea level, but none of the Scandinavian runners achieved such high individual values as observed in some Kenyan runners. It was concluded that it is physical activity during childhood, combined with intensive training in boys, that leads to higher VO_2max. Using the correlation between oxygen deficiency (AOD) and lactate concentration, which contribute to the values of the aerobic energy system in middle distance runners, Duffield et al. (2005), on a sample of 10 runners at 3000m (8 men and 2 women) and 14 runners at 1500m (10 men and 4 women) measured oxygen deficiency (AOD) and lactate concentration. The results of the analyzes

showed that the relative contribution of the measure-based aerobic energy system (AOD) for 3000 m was 86% (men) and 94% (women), while for 1500 m it was 77% (male) and 86% (female). Estimation of aerobic energy consumption based on lactate concentration did not differ between subjects in relation to gender and discipline ($p>0.05$). McConnell & Clark (1988) studied a sample of 10 middle distance runners by analyzing the value of the maximum oxygen consumption VO_2max when performing the test where the speed increase protocol was changed 4 times, each by 2.5% every 2 minutes of performance. The results showed that there were no significant differences in the maximum oxygen consumption VO_2max between the protocols (P1, 65.0 +/- 5.6 ml/kg/min; P2, 64.5 +/- 5.3 ml/kg/min; P3, 66.2 +/- 3.9 ml/kg/min; P4, 64.7 +/- 5.8 ml/kg/min). By a test performed by repeating 4 protocols (where the running speed increased by 0.3 km/h every 25 seconds), Lourenço et al. (2011) analyzed maximal oxygen consumption VO_2max, ventilation threshold (VT), and respiratory compensation (RCP), in a sample of 11 male middle-distance runners. After the performed analyzes, no significant differences were found in any of the analyzed parameters during the implementation of the test protocol ($p> 0.05$). Foster et al. (1978) analyzed the maximum oxygen consumption VO_2max, muscle fiber composition and dehydrogenase (SDH) in a sample of 26 runners at medium distances using a treadmill test (running 1 mile, 2 miles and 6 miles). The results showed a low correlation between SDH and VO_2max ($r = -0.11$ for 1 mile, $r = -0.14$ for 2 miles and $r = -0.20$ for 6 miles), while the correlation of muscle fiber composition with VO_2max was at medium level ($r = -0.52$ for 1 mile, $r = -0.54$ for 2 miles and $r = -0.55$ for 6 miles).

Table 3. *Functional abilities researched in long distance runners*

Author	Sample of respondents	Tests	Results
Bilat et al. (2003)	20 (elite Kenyan runners: 13 men and 7 women)	– VO_2max and speed at lactate threshold (vLT)	– the mean speed between vVO_2max and vLT did not differ significantly from the speed at 10 km, regardless of gender or type of training
Cavanagh & Williams (1982)	10 (recreational long-distance runners)	– O_2 intake	– the mean increase in VO_2 was 2.6 and 3.4 ml, respectively. kg-1. min-1 at extreme short and long stride lengths
Coetzer et al. (1993)	9 white and 11 black South African middle and long distance runners	– race at 3000m and 5000m	– black runners had lower blood lactate concentration during exercise – -time to fatigue was longer at black runners
Conley & Krahenbuhl (1980)	12 (long distance runners)	– oxygen intake (VO_2) – VO_2max	– running economy makes up a large and significant amount of differences observed in the 10 km race
Davies & Thompson (1979)	13 (male ultramarathoners) and 9 (female marathoners)	– VO_2max	– VO_2max in men was higher than in women, but the consumption of O_2 for a given speed was the same for both sexes
Craig & Morgan (1998)	9 (middle and long distance runners)	– VO_2max – running economy (RE) – oxygen deficit (AOD)	– no significant correlation was found between the 800 m running time and AOD
Boileau, Mayhew, Riner, & Lussier (1982)	74 elite runners (42 middle distance - MD, 32 long distance - LD)	– VO_2max	– mean VO_2max of LD runners was significantly higher than the value for the MD group – VO_2max is highly correlated with racing performance in the MD group
Daniels & Daniels (1992)	20 female and 45 male middle and long distance runners	– VO_2max – Heart rate (HR) – blood lactate level (HLa)	– men have higher VO2max than women and used less oxygen at normal absolute speeds, but VO_2 did not differ between men and women
Taunton, Maron, & Wilkinson (1981)	15 male middle (MD) and long (LD) distance runners	– VO_2max – blood lactate level	– VO_2max values were higher in LD runners – blood lactate values were higher in the MD group compared to LD runners
Powers & Corry (1982)	5 (swimmers) 5 (cross-country runners)	– VO_2max	– VO_2max significantly higher in runners than in swimmers

Billat et al. (2003) analyzed VO_2max, speed at VO_2max (vVO_2max) and speed at the lactate threshold (vLT) in a sample of 20 elite Kenyan runners (13 men and 7 women) by 400 m track exhaustion test. They concluded that the mean velocity between vVO_2max and vLT did not differ significantly (P 0.87, 0.25, 0.87) regardless of gender or degree of training. Cavanagh & Williams (1982) dealt with O_2 intake by the *Douglas Bag* method, in 10 recreational runners (mean VO_2max values of 64.7 ml/kg/min). The increase in O_2 was 2,6 and 3,4 ml/kg/min by changing the running technique. Comparing white and black runners at 3000 m and 5000 m, Coetzer et al. (1993) in a sample of 9 white and 11 black runners concluded that the superior

performance of black runners did not result from a higher percentage of type I fibers, but from black runners having lower blood lactate levels during load and longer time until onset of fatigue compared to white runners (169 +/- 65 seconds vs. 97 +/- 69 seconds; $p < 0.05$). In a sample of 12 middle distance runners, Conley & Krahenbuhl (1980) analyzed the correlation of VO_2max with running economy. The results showed that VO_2max has no statistically significant correlation with running economy ($r = -0.12$, $p = 0.35$), but noted that among highly trained and experienced runners of similar ability and similar VO_2max running economy makes a large and significant difference in achieved results of running longer distances. Comparing the maximum oxygen consumption VO_2max in a sample of 13 male marathoners and 9 female marathoners, Davis & Thompson (1979) concluded that a statistically significant difference ($p < 0.001$) was observed between the value of VO_2max in men of 72.5 ml/kg/min and in women of 58.2 ml/kg/min. The problem of predicting middle distance running results based on VO_2max values, running economy (RE), and oxygen deficiency (AOD) was addressed by Craing & Morgan (1998). On a sample of 9 male medium and long distance runners (age 24.7 +/- 4.5 years, body weight = 69.4 +/- 8.5 kg, maximum oxygen consumption VO_2max 64.8 +/- 4.5 ml/kg/min), they analyzed the prediction of middle distance running results based on VO_2max values, running economy (RE) and oxygen deficiency (AOD). They concluded that no significant correlation was found between 800m running time and oxygen deficiency (AOD), and also that 800m running time could not be predicted based on the values of the other variables analyzed (VO_2max and running economy (RE). By analyzing the maximum oxygen consumption at different running speeds, on a sample of 74 elite runners (42 middle distance runners (MD) and 32 long distance runners (LD), Boileau et al. (1982) came to certain conclusions. The mean value of maximum oxygen consumption VO_2max (ml/kg/min) in LD runners (76.9 ml/kg/min) was significantly higher than the value for MD runners (68.9 ml/kg/min) and a statistically significant difference ($p < 0.01$) was found. At different running speeds, the relative oxygen consumption (% VO_2) was lower for the LD group of runners by an average of 8% and a statistically significant

difference was found ($p < 0.01$). They also found that maximal oxygen consumption VO_2max was more correlated with racing performance in the MD group of runners ($r = 0.70$) than in the LD group of runners ($r = 0.32$). Maximum oxygen consumption, heart rate and blood lactate levels, in a sample of 20 female and 45 male runners at medium and long distances, were also analyzed by Daniels, J. & Daniels, N. (1992) and they presented the obtained results. The results showed that men were taller, heavier, had a lower sum of six skin folds and higher maximum oxygen consumption VO_2max than women ($p < 0.05$). Men used less oxygen (ml/kg/min) at normal absolute speeds, but no statistically significant difference was found between men and women. When comparing men and women with equal maximum oxygen consumption VO_2max, men were significantly more economical in energy consumption. It was concluded that men are more economical than women at absolute running speeds, but when expressed in ml/km/kg there are no differences at similar running intensities. Also, when comparing men and women with equal maximum oxygen consumption VO_2max, men show better aerobic abilities. Maximum oxygen consumption VO_2max and blood lactate levels in middle and long distance runners were also tested by Taunton et al. (1981). They measured the value of maximum oxygen consumption VO_2max and the level of lactate in the blood in 15 male medium and long distance runners. The presented conclusions indicate that the values of maximum oxygen consumption VO_2max were significantly higher in long-distance runners (68.7 ml/kg/min) compared to middle distance runners (62.8 ml/kg/min). Also, the values of lactate in the blood after maximum work were significantly higher in the group of runners at medium distances (15.0 mmol/l) compared to runners at long distances (11.9 mmol/l). Coory & Powers (1982) found that runners have higher VO_2max than swimmers.

Table 4. *Impact of training on functional abilities*

Author	Sample	Tests	Results
Toncev (1988)	80 (students)	– Aerobic abilities	– Aerobic abalities improved
Burke et al. (1994)	80 (age 17 years +/- 6 months)	– lactate concentration and VO_2max	– results in both types of interval training showed an increase in VO_2max by 5% and 6%, lactate threshold by 19.4% and 22,4% and ventilatory threshold by 19.5% and 18.5%, respectively.
Stoiljkovic, Brankovic, Stoiljkovic & Joksimovic (2005)	90 (age 11 i 12 years)	– systolic and diastolic blood pressure – pulse frequency in load – absolute oxygen consumption – relative oxygen consumption	– increase in the level of functional abilities in the experimental period by applying the circular form of work is higher in the experimental group compared to the control group
Jakovljevic & Batricevic (2008)	38 (14 i 15 years +/- 6 months)	– heart rate while resting, – vital capacity of lungs, – systolic and diastolic blood pressure	– established a statistically significant difference in the transformation processes of the experimental model in the vital capacity of lungs and systolic and diastolic blood pressure
Franch, Madsen, Djurhuus, & Pedersen (1998)	36 (recreationists)	– VO_2max – RE (running economy)	– VO_2max and running speed at VO_2max are increased – Running economy is improved
Helgerud et al. (2007)	40	– VO_2max – heart strike volume (SV), – blood volume, – lactate threshold (LT) – running economy (RE)	– training process significantly influenced the increase of VO_2max in relation to the initial state – running economy (RE) increased statistically significantly by 10%

Dealing with the influence of a certain experimental program on functional abilities, Toncev (1988) tested 80 respondents aged 17 years +/- 6 months and came to the result that after the experimental exercise program, the functional abilities of the subjects were improved. Burke et al. (1994) dealt with a similar issue, they examined the effect of interval training on lactate level (lactate threshold) and VO_2max, in 80 respondents aged 17 years +/- 6 months. They concluded that VO_2max increased by 6% and the lactate threshold by 22.4%. Stoiljkovic et al. (2005) examined the influence of circular training on systolic and diastolic blood pressure, heart rate at workload, absolute and relative oxygen consumption, on a sample of 90 respondents aged 11 and 12 years. The obtained analysis results show that all parameters of functional abilities are increased after the circuit training treatment. The training model, which was aimed at developing functional abilities, was analyzed by Jakovljevic & Betricevic (2008) and they measured resting heart rate, vital capacity, systolic and

diastolic blood pressure in a sample of 38 respondents aged 14 and 15 years before the experimental training treatment. They came to the conclusion that the experimental treatment of training had a positive impact on the development of all abilities. By analyzing the impact of the training process in the frequency of exercise of 3 times a week conducted for 6 weeks, on a sample of 36 men engaged in recreational running, Franch et al. (1998) analyzed maximal oxygen consumption VO_2max and running economy (RE). Subjects were divided into three groups that conducted different trainings (exhaustive training with running longer distances (DT), long training (LIT) and training with running over shorter sections (SIT) .The results showed that VO_2max increased by 5.9 % ($p < 0.0001$), 6.0% ($p < 0.0001$) and 3.6% ($p < 0.01$) in DT, LIT and SIT, and running speed at VO_2max by 9% ($p < 0.0001$), 10% ($p < 0.0001$) and 4% ($p < 0.05$), respectively. Efficiency of the training process lasting 8 weeks on VO_2max, heart strike volume (SV), lactate threshold (LT) and running economy (RE), on a sample of 40 men, divided into four groups - 70% of maximum heart rate; at the lactate threshold (85% HRmax); interval running 15/15 (15 s running at 90-95%; 4 x 4 min interval running (4 min running at 90-95% HRmax), were analyzed by Helgerud et al. (2007), and concluded that aerobic interval training of high intensity resulted in significantly increased VO_2max compared to long-distance training intensity and lactate threshold ($P < 0.01$) .The percentage of increase for groups of 15/15 and 4 x 4 min was 5.5 and 7.2%, respectively, reflecting an increase in VO_2max from 60.5 to 64.4 ml x kg (-1) x min (-1) and 55.5 to 60.4 ml x kg (-1) x min (-1). SV increased significantly by approximately 10% after interval training ($P < 0.05$).

DISCUSSION

As can be seen in Table 1, to assess the functional abilities of short-distance runners, research was conducted on a relatively small sample - from 9 (Spencer, Gastin, & Payne, 1996) to 34 (Kurelic et al ., 1975), and mostly all are based on a comparison of the functional abilities of short distance runners with the functional abilities of middle distance runners, in which oxygen consumption and maximum oxygen

consumption were determined (Roberts et al., 1979; Nummela & Rusko, 1995; Nagasawa, 2013). as well as assessed the energy of aerobic and anaerobic systems (Spencer, Gastin & Payne, 1996; Spencer & Gastin, 2001) and muscle reoxygenation rate (Nagasawa, 2013). The results of the research indicate that middle distance runners have a higher maximum oxygen consumption and a higher aerobic threshold than short distance runners (Roberts et al., 1979), that the relative energy contribution during the first 15 seconds of running decreases in both, and that there is no difference in the value of oxygen deficiency (Nummela & Rusko, 1995; Spencer, Gastin, & Payne, 1996). Also, research has shown that the maximum oxygen consumption is higher in short distance runners compared to middle distance runners during the first 400m in the 800m and 1500m runs (Spencer, Gastin, & Payne (1996), that in short distance runners oxygen deficiency increases with duration of load (Spencer & Gastin, 2001), and that the rate of muscle relaxation and maximum oxygen consumption are positively correlated (Nagasawa, 2013). The sample of research respondents listed in Table 2 ranged from 6 to 431 runners on middle distances of different ages and genders, and the research dealt with the assessment of submaximal and maximal oxygen consumption. Table 2 shows various studies of functional abilities, both VO_2max and lactate levels during and after exercise, then energy consumption, up to heart rate. Methods for estimating VO_2max, both submaximal and maximal, and oxygen consumption during running were also examined. All this research was analyzed in connection with running middle and long distances. Evidence of a statistically significant correlation of functional abilities with running at middle distances was found in three studies (Krsmanovic, 1987; Vuksanovic, 1999; Duffield, Dawson & Goodman, 2005; Daniels, Oldridge, Nagle & White, 1978). The analysis of oxygen consumption, at different running speeds, was done by several researches, which came to different conclusions. Confirmed changes in VO_2max at different running speeds, and their mutual correlation were determined in the research (Stoiljkovic et al. 2004; Mayhew, 1977; Pate, Macera, Bailey, Bartoli & powell, 1992; Daniels & Oldrige, 1971; Foster, Costill, Daniels & Fink, 1978), while research (Fletcher, Esau & Macintosh,

2009; Brisswalter & Legros, 1994; McConnell & Clark, 1988; Lourenço, Barreto Martins, Tessutti, Brenzikofer, & Macedo, 2011) did not confirm the correlation between VO_2max and running speed. The correlation between VO_2max and lactate levels was addressed by (Svedenhag & Sjödin, 1984,) who found differences in VO_2max and lactate levels and proved that long distance runners have lower blood lactate concentrations than middle distance runners. Comparing different groups of respondents and their functional abilities (Helgerud, 1994; Saltin et al. 1995, Allen, Seals, Hurly, Ehsani & Hagberg, 1985) concluded that men have higher VO_2max than women, and that there is no difference between European and African runners, and that older and more experienced runners have lower VO_2max than younger runners, but also achieve lower blood lactate levels with a higher percentage of their own VO_2max. By estimating VO_2max by different methods (Gasiin, Costill, Lawson, Krzeminski & McConell 1995), they concluded that the AOD method is very reliable in estimating VO_2max.

Table 3 shows papers that dealt with the values of VO_2max depending on the length of the distance, also analyzed the values of VO_2max in relation to the gender of respondents and economy of performing the running technique. A statistically significant difference between male and female long distance runners in VO_2max consumption was demonstrated by (Davies & Thompson, 1979, Daniels & Daniels 1992), while (Daniels & Daniels 1992, Bilat & et al. 2003) proved that running speed at VO_2max and the lactate threshold does not differ statistically in relation to the gender of runners and that VO_2 does not differ between the sexes at normal absolute running speeds. Analyzing the correlation of long distance running technique with functional abilities (Cavanagh & Williams, 1982; Conley & Krahenbuhl, 1980) proved the statistical association of running economy with VO_2max values, while (Craig & Morgan, 1998) found that there was no statistical association between running results at 800m and oxygen deficit values. Comparing VO_2max values and lactate levels between middle and long distance runners (Coetzer et al. 1993; Boileau, Mayhew, Riner & Lussier, 1982; Taunton,

Maron & Wilkinson, 1981,), they proved that black runners have lower lactate concentrations and longer period of entering fatigue than white runners, then that long distance runners have higher VO_2max, and lower blood lactate levels than middle distance runners. Comparing VO_2max values in different sports (Powers & Corry, 1982) proved that long distance runners have a statistically higher VO_2max value than swimmers. Rotstein et al. (1986) found that nine-week interval training in athletes led to an increase in anaerobic threshold, VO_2max and anaerobic capacity, as measured by the Wingate test. The role of aerobic and anaerobic capacities or the contribution of aerobic and anaerobic energy sources in running depends on the intensity and duration of running (Skof, Kropej & Milic, 2002). Several previous studies (Morgan, Baldini, Martin & Kohrt, 1989; Powers, Dodd, Deason, Byrd, & McKnight, 1983) have shown that maximal oxygen consumption (VO_2max), running speed at the lactate limit, and running economy at higher speeds are significantly associated with success in running.

Bernstein (1966) noted that in no area of human physiology is there such an intensity of phylogenetic progress as in the area of motor functions. For these reasons, in order to establish the necessary and essential balance between vegetative and motor functions, various physical exercises are widely used, in terms of their dynamics and kinematics, which have a powerful and concentrated effect on different parts of the central, peripheral and vegetative nervous system, which contributes to their balance, and the application of appropriate diagnostic procedures and data analysis methods provides insight into the level of ability, characteristics and motor skills of the athlete, thus learning about possible barriers that are potential obstacles to further development and progress of the athlete (Mueller, 1999; Weineck, 2007 Reilly, 2007).

Table 4 shows the papers that analyzed the influence of a certain form of training process on functional abilities. By analyzing the effects of interval and circular form of training on functional abilities (Burke & et al. 1994, Stoiljkovic, Brankovic, Stoiljkovic & Joksimovic, 2005) proved a statistically significant difference between the initial and final measurement of certain

functional abilities (lactate concentration and VO_2max). By monitoring VO_2max values, running economy, and vital lung capacity and systolic and diastolic blood pressure during the training process (Toncev, 1988; Jakovljevic & Baricevic, 2008; Franch, Madsen, Djurhuus & Pedersen, 1998; Helgerud et al., 2007), found a statistically significant increase in VO_2max values between the initial and final measurements, an increase in vital capacity, a decrease in systolic and diastolic blood pressure, and an increase in running economy. Testing 6 decathlon athletes, Popov (1980) found that certain parts of sprint training have a positive effect on functional abilities. Petrovic & Kukric (2006), on a sample of 12 respondents aged 20 years +/- 6 months, concluded that the training model had a positive impact on increasing functional abilities.

CONCLUSION

After analyzing all the above papers which have dealt with the functional abilities of short and medium distance runners, it can be seen that it is shown that middle distance runners have better functional abilities, ie higher maximum oxygen consumption, higher aerobic threshold and lower oxygen deficit than short distance runners. A review of all papers dealing with the functional abilities of middle distance runners, indicated that there is a large correlation between maximum oxygen consumption and lactate levels with running speeds and results achieved at middle distances, and it was also found that male middle distance runners have higher maximum oxygen consumption and lower lactate levels than female runners. However, research on the functional abilities of long distance runners has shown that these runners have higher maximum consumption and lower lactate levels than middle distance runners, and that gender has a significant effect on the manifestation of maximum oxygen consumption, but that there are no differences between the sexes at running speeds at the level of maximum oxygen consumption and lactate levels. The analysis of papers that dealt with the influence of the training process on functional abilities showed that the implementation of various forms of training methods led to a statistically significant

increase in the value of maximum oxygen consumption, vital lung capacity, and running economy, but also to a decrease in systolic and diastolic blood pressure.

The limitation of this study was a limited access to the research studies, and a limited methodology applied in them, while many studies had too few respondents of different populations with a small number of elite runners, which caused low statistical power to draw general conclusions. Also, there is insufficient information on many years of experience, level of sports form, race categories, and descriptions of training and methods, which would enable the implementation of sufficient statistical analyzes, obtaining empirical information based on evidence and drawing valid conclusions. Useful methods were highlighted in the training papers, but short-term data collection did not include a sufficient number of papers on the long-term impact of training. Accordingly, there is a need for a more systematic approach to research and the implementation of complex studies with a sufficient number of runners of all ages and both sexes of the elite level, to enable meaningful statistics, analysis and interpretation. Also, a cooperation of academic researchers, clubs and athletes in Europe is needed, which would enable the implementation of significant studies that provide a basis for evidence of improved performance and progress through the training system.

The results identified in this review provide a starting point for future research which identifies and quantifies predictors of functional performance as factors of success in short, middle, and long distance running.

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PARAMETERS OF FUNCTIONAL ABILITIES IN RUNNING – RESEARCH REVIEW

SAŽETAK

Trčanje kao atletska disciplina iziskuje velik nivo izdržljivosti i brzinske izdržljivosti, što je u direktnoj vezi sa kardiovaskularnim i respiratornim sistemima, odnosno sa sposobnošću organizma sportiste da podnese opterećenja koja, pa se kao relevantni faktori za uspjeh trčanju navode: anaerobna snaga i maksimalna potrošnja O_2, koncentracija mliječne kiseline i manjak kisika, sposobnost podnošenja stresa, visoko sposobnost koncentracije i njeno zadržavanje tokom dužeg vremena. Mnogo je istraživanja koja su se bavila izučavanjem parametara funkcionalnih sposobnosti u pokušaju nalaženja najefikasnijeg načina poboljšanja istih, a budući da je mnogo sličnih i različitih podataka o toj tematici ovaj rad je urađen sa ciljem klasifikovanja dostupnih radova domaćih i stranih autora čime bi se izveli zaključci primjenljivi kako u praksi tako i za dalja istraživanja.

Za potrebe ovog istraživanja analizirani su originalni naučni radovi koji su se bavili funkcionalnim sposobnostima kao faktorima uspjeha u trčanju na kratke, srednje i duge distance te uticajem treninga na funkcionalne sposobnosti, pronađeni na elektronskim bazama podataka - Medline, PubMed, Researchgate, Web of Science and Google Scholar. Istraživanja korištena u ovom pregledu pratila su transverzalno vrijednosti submaksimalne i maksimalne potrošnje kiseonika, energetske sisteme, vrijednosti frekvencije srca, plućnu ventilaciju, koncentraciju lakatata u krvi, kao i njhove promjene nakon longitudinalne provedbe eksperimentalnih protokola i trenažnih procesa. Budući da su prikupljena istraživanja imala premalo ispitanika različite populacije sa malom brojnošću elitnih trkača, te da nisu imala dovoljno informacija o dugogodišnjem iskustvu, nivou sportske forme, kategorijama trka, te opisa treninga i metoda, dobijanje empirijskih informacija utemeljenih na dokazima bilo je ograničeno, kao i izvedba valjanih zaključaka. Shodno navedenom, postoji potreba za više sistematskim pristupom istraživanjima i provedbi kompleksnih studija sa dovoljnim brojem trkača svih uzrasta, oba pola elitnog nivoa, te saradnja akademskih istraživača, klubova i sportista što bi omogućilo provođenje studija koje bi omogućile značajne statističke podatke, analize i interpretacije. Rezultati identifikovani u ovome pregledu pružaju polazište za buduća istraživanja koja identifikuju i kvantifikuju prediktore funkcionalnih performansi kao faktore uspjeha trčanja na kratkim, srednjim i dugim distancama.

Ključne riječi: *maksimalna potrošnja kiseonika, koncentracija laktata, kratke distance, srednje distance, duge distance, trenažni proces*

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INFLUENCE OF ATTENDING EXTRACURRICULAR SPORTS ACTIVITIES ON FUNCTIONAL ABILITIES OF FIFTH AND SIXTH GRADE ELEMENTARY SCHOOL STUDENTS

UTJECAJ IZVANNASTAVNIH SPORTSKIH AKTIVNOSTI NA FUNKCIONALNE SPOSOBNOSTI UČENIKA OSNOVNIH ŠKOLA PETOG I ŠESTOG RAZREDA

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ABSTRACT

The sample consisted of 121 respondents from fifth and sixth-grade elementary schools from the City of Zadar. A research was conducted to determine the differences between students who, in addition to physical education and health education, also attend some other form of extracurricular sports activity. By conducting a descriptive analysis, we obtained results that show us that male students engaged in extracurricular activity achieved 21.28% better average results than respondents who do not engage in extracurricular activities. Female respondents engaged in extracurricular activities achieved 9.16% better results than respondents who did not engage in extracurricular activities (better scores in the test to assess functional ability (F6 test)). Using the t-test, we found that empirical levels of significance were statistically significant (p = 0.000) for all respondents in both sexes in functional abilities (F6 test). The authors can claim that students attending some forms of extracurricular sports activity have a better score in the variable F6. By performing regression analysis, authors cannot predict the result in the F6 test based on anthropometric characteristics of body height (TV) and body weight (TT). To improve the functional abilities of students, each teacher should encourage them to attend some additional forms of extracurricular sports activities in the form of improving the overall anthropological status.

Key words: *extracurricular activities, physical education, functional abilities*

INFLUENCE OF ATTENDING EXTRACURRICULAR SPORTS ACTIVITIES ON FUNCTIONAL ABILITIES OF FIFTH AND SIXTH GRADE ELEMENTARY SCHOOL STUDENTS

INTRODUCTION

In the Republic of Croatia, physical education classes in the upper grades of primary school are held twice a week for 45 minutes. The question arises, at what level are students satisfied with physical activity by chronological and biological age if two school hours meet the curriculum. Among fifth and sixth-grade elementary school students, extracurricular sports activities are a common choice. Among the wide range of activities offered to students, sports activities according to research take first place. The sport will have two effects on a child; the first is the impact on health and a healthy lifestyle, and the second, perhaps more important, is the one that affects the psyche of children (Stevanović, 2003). Determining the current state of the student as an individual, as well as of the group as a whole, enables the teacher to directly control his work and to program and implement the planned contents in a quality manner in order to achieve the set goals (Androja, T. Bavčević & D. Bavčević, 2019).

For many years, sports scientists have been trying to find ways to evaluate functional ability in several selected populations. The importance of an adequate level of functional abilities arises primarily from health reasons, as a kind of protective measure against a predominantly sedentary lifestyle and its consequences: the emergence of increasing obesity and diabetes (Hills, King, & Armstrong, 2007). The optimal level of functional abilities can be achieved by programmed fitness training, and that part of it is aimed at raising the efficiency of the transport (cardiovascular and cardio-respiratory) system and increasing anaerobic capacity. The structure of functional ability training consists of stimuli of aerobic and anaerobic character, which thus cover the area of activation of different energy systems (Milanović, 2013).

Research has found that more regular extracurricular sports activities are carried out more often in environments that support it and appreciate it both in material and professional terms. Experts have determined that for optimal growth and development and the health of each person, it is necessary to provide appropriate material conditions, professional staff, and to monitor and evaluate the appropriate characteristics and abilities (Findak, Metikoš, Mraković, & Neljak, 1996).

Given the unavailability and complicated application of these measures in the teaching of physical education and health, the most appropriate assessment of functional abilities of students (general aerobic ability) is performed by running 3 minutes (F3) for primary school students, and 6 minutes (F6) for upper primary school students and high school students (Findak, 1999). Sertić, Vračan, & Baić, (2005) conducted a study comparing twelve-year-old judo fighters and non-sports males and obtained significant differences in the F6 test. Lorger, Bujan, & Ovčarić, (2008) tried to determine the anthropological model of a successful handball player in school sports and obtained F6 test values higher than the grade excellent compared to orientation norms (Findak, 1999).

The problem with this paper is to examine whether students who attend extracurricular activities run more meters than those who do not attend a 6-minute running test. The main goal of this research is to determine whether there are quantitative differences between fifth and sixth-grade students of elementary school from Zadar, in the functional ability test, who attend some forms of extracurricular sports activities and those students who do not attend any forms of extracurricular sports activities.

METHODS

The sample in this study consisted of 121 fifth and sixth-grade elementary school students from Zadar, aged 11 and 12 years - 61 respondents are male, while 60 respondents are female. The sample was also divided into respondents who attend in additional activities outside the subject of physical education and those who do not. 33 male students are engaged (with an average body weight of 42.06 kg and an average body height of 150.02 cm), while 28 are not engaged (with an average body weight of 44.25 kg and an average body height of 149.73 cm). Regarding female students, 31 of them are engaged (with an average body weight of 41.08 kg and an average body height of 151.08 cm), while 29 of them are not engaged in any extracurricular activities (with an average body weight of 43.44 kg and with an average body height of 150.64cm).

Table 1. *Sample size*

gender	activity	frequency	MTT	MTV
male	yes	33	42,06	150,02
	no	28	44,25	149,73
	in total	61		
female	yes	31	41,08	151,08
	no	29	43,44	150,64
	in total	60		

For the purpose of the research we were use a variable for assessing the functional abilities of students (general aerobic abilities) - running 6 minutes test - (F6). Test was conducted on sports playground near schools due the lessons of physical education, in morning hours.

The entry and processing of complete data were done with the help of the computer program Statistica ver. 12.0.

RESULTS

Table 1. *F6 test results in all subjects*

gender	activity	frequency	Min F6	Max F6	Mean F6	SD	K-S test
male	da	33	840,00	1368,00	1208,73	110,66	0,078
	ne	28	600,00	1260,00	996,64	145,06	0,417
female	da	31	970,00	1248,00	1076,33	77,65	0,127
	ne	29	720,00	1128,00	986,00	93,59	0,478

Table 1. shows the results of all subjects on the F6 aptitude test. Based on the average value of the results of the F6 test, it can be noticed that the respondents of both genders who are engaged in extracurricular activities achieved better results than those who are not.

Thus, male respondents who attend extracurricular activities achieved 21.28% better average results than respondents who do not engage in extracurricular activities. Female respondents engaged in extracurricular activities achieved 9.16% better results than respondents who did not engage in extracurricular activities.

Graph 1. *Presentation of F6 test results in subjects of both genders who are engaged in additional activities and those who are not engaged, and the differences between the achieved results*

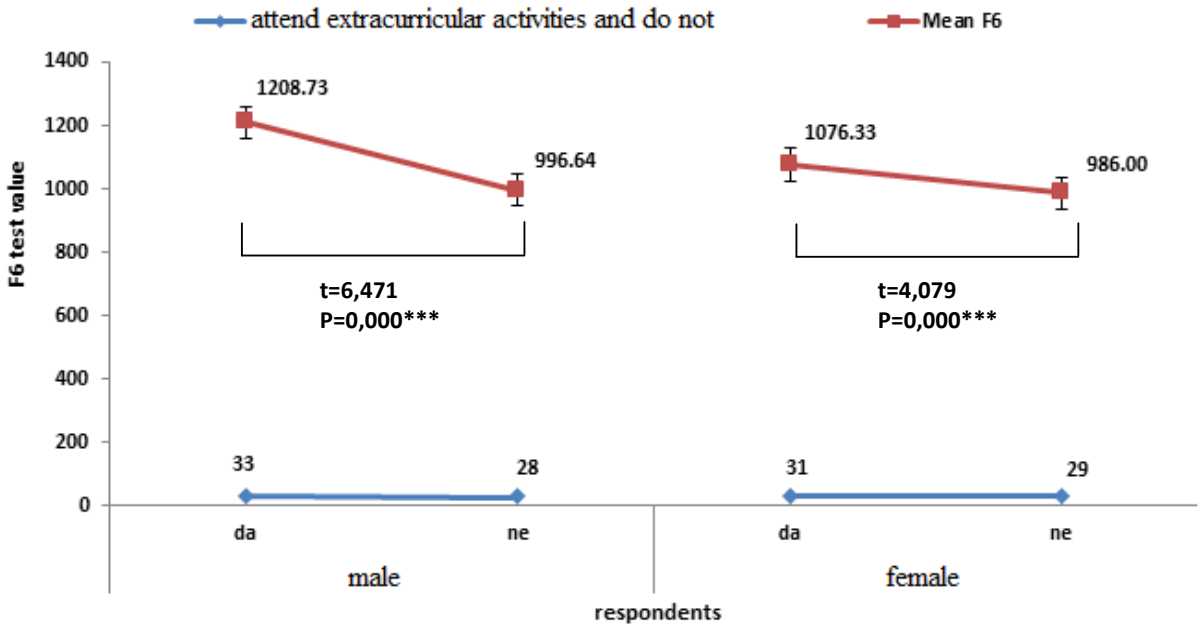

Table 2. *Differences between F6 test results in male and female subjects who engage in extracurricular activities and who do not engage in extracurricular activities*

Variable	N (no)	N (yes)	Mean (no)	Mean (yes)	t- value	df	p
F6 male	28	33	996,64	1208,73	6,471	59	**0,000**
F6 female	29	31	986,00	1076,33	4,079	58	**0,000**

Based on the values of the T-test results for the independent samples shown in the table, it can be concluded that there is a statistically significant difference in both genders, at 0.005 between the results achieved on the aptitude test between subjects engaged in extracurricular activities and those not engage in extracurricular activities.

Table 3. *Differences between the results of male and female respondents engaged in extracurricular activities in the F6 test*

Variable	N male	N female	Mean male	Mean female	t- value	df	p
F6	33	31	1208,73	1076,33	5,507	62	**0,000**

Based on the values of the T-test results for the independent samples shown in the table, it can be concluded that there is a statistically significant difference at the level of 0.005 between the results achieved on the aptitude test between male and female subjects engaged in extracurricular activities.

It can be concluded that male respondents achieved better results by 12.30%.

Table 4. *Regression analysis (prediction of F6 test results based on individual anthropometry variables - body height and body weight)*

Respondents	Independent variables	Non-standardized coefficient		Standardized coefficient	T	Sig.	Dependent variable
		B	Standard error	Beta			
Male	constant	1778,296	503,619		3,531	0,001	**F6**
	TV	-3,173	4,050	-0,254	-0,783	0,440	
	TT	-2,226	2,955	-0,244	-0,753	0,457	
Female	constant	967,783	522,443		1,852	0,075	**F6**
	TV	1,391	3,950	0,092	0,352	0,727	
	TT	-2,474	2,797	-0,232	-0,885	0,384	

Examining the prediction of test results to assess functional abilities (F6), based on anthropometric characteristics of body height (TV) and body weight (TT) in both genders, it was observed that in subjects of both genders anthropometric characteristics of body height (TV) and body weight), do not statistically significantly affect the results of the test for the assessment of functional abilities (F6). Based on these results, it can be assumed that the

results of the F6 test cannot be predicted based on the anthropometric characteristics of body height (TV) and body weight (TT) in both genders.

DISCUSSION

The authors obtained data that male students attending extracurricular activities are better in the F6 test by as much as 21.28%, while girls are better by 9.16%. The reason for the previously written data will be explained through the following discussion. The T-test for independent samples was used to establish the differences between those students who attend physical education and health education and some additional form of extracurricular sports activities and those who do not. With the help of an empirical level of significance that is statistically significant, according to the assessment segment between the criterion variable F6 test of male students and female students, we can claim that students who attended some forms of extracurricular sports activity have a better result in variable F6 (F6 male = 0,000, F6 female = 0.000). Also, the difference between male and female students is statistically significant (0,000). The T-test showed us that there is a statistically significant difference between both sexes in the F6 test in those who engage and those who do not engage in extracurricular activities. The result is an indication that extracurricular activities can significantly contribute to the development of functional abilities. It is not just about a better result, better functional abilities correlate with many other positive factors for the health and functionality of the entire human organism. Male students had a 12.30% better score in the F6 test than female students. Girls enter puberty earlier, but it can also have negative connotations.

The anthropometric composition of the body is similar in girls and boys in early childhood. Later, girls begin to gain more fat, and boys, starting in adolescence, begin to grow lean mass much more than girls. Also, on average, boys are more involved in sports than girls, and especially sports such as football, basketball, handball where racing shares are pronounced. While girls are more involved in sports such as volleyball, dance, wherein training they have a greater emphasis on the technical part and the beauty of the performance, and less on functional abilities. By performing regression analysis, as

previously stated, we cannot predict the result in the F6 test based on anthropometric characteristics of body height (TV) and body weight (TT). At the ages of 11 and 12, girls begin to enter puberty, but rapid growth and development do not necessarily mean a better correlation with better results in sports activities. The exact opposite can happen! Each child is a separate individual, and the authors generally claim that at this age one cannot conclude that someone will be better in the F6 test due to more pronounced anthropometric characteristics.

CONCLUSION

The obtained results show that there are significant differences between fifth and sixth-grade students of primary schools from Zadar who actively practice extracurricular sports activities, ie sports training and those who do not. The research confirmed that additional sports activity in addition to teaching physical education and health culture has a positive effect on the functional abilities of students.

The number of hours and the duration of a lesson in physical education and health education in primary school is not sufficient for the development of functional ability. In order to improve the functional abilities of students, each teacher should encourage them to attend some additional forms of extracurricular sports activities in the form of improving the overall anthropological status and help growth and development. Also, the Ministry of Science and Education should consider introducing an additional physical education class in the school week. If this is not possible, students should be educated more about the importance of playing sports on health status. Lower functional abilities have consequences and higher risks of various diseases. Therefore, there is no activity such as sports training to prevent potential problems. Accordingly, the results can be of great use to coaches and teachers of physical education for better planning and programming the training cycles and the teaching process, guidance, control of individual level of training, monitoring of growth and development, development of basic and specific motor skills, control of the realization of teaching and in general the entire teaching of physical education (Androja, T. Bavčević & D. Bavčević,2019).

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INFLUENCE OF ATTENDING EXTRACURRICULAR SPORTS ACTIVITIES ON FUNCTIONAL ABILITIES OF FIFTH AND SIXTH GRADE ELEMENTARY SCHOOL STUDENTS

SAŽETAK

Uzorak je činio 121 ispitanik iz petih i šestih razreda osnovnih škola grada Zadra. Provedeno je istraživanje kako bi se utvrdile razlike između učenika koji, osim tjelesnog i zdravstvenog odgoja pohađaju i neki drugi oblik izvannastavne sportske aktivnosti. Provođenjem deskriptivne analize dobili smo rezultate koji nam pokazuju da su muški učenici koji se bave izvannastavnom aktivnošću postigli 21,28% bolje prosječne rezultate od ispitanika koji se ne bave izvannastavnim aktivnostima. Ispitanice uključene u izvannastavne aktivnosti su postigle 9,16% bolje rezultate od ispitanica koje se nisu bavile izvannastavnim aktivnostima (bolji rezultati u testu za procjenu funkcionalne sposobnosti (F6 test)). Korištenjem t-testa otkrili smo da su empirijske razine značajnosti statistički značajne (p = 0,000) za sve ispitanike kod oba spola u funkcionalnim sposobnostima (F6 test). Autori mogu tvrditi da učenici koji pohađaju neke oblike izvannastavnih sportskih aktivnosti imaju bolji rezultat u varijabi F6. Izvođenjem regresijske analize autori ne mogu predvidjeti rezultat u F6 testu na temelju antropometrijskih karakteristika tjelesne visine (TV) i tjelesne težine (TT). Broj nastavnih sati i trajanje sata tjelesnog odgoja u osnovnoj školi nije dovoljan za razvoj funkcionalne sposobnosti. Da bi poboljšali funkcionalne sposobnosti učenika, svaki bi ih učitelj trebao potaknuti da pohađaju neke dodatne oblike izvannastavnih sportskih aktivnosti u vidu poboljšanja cjelokupnog antropološkog statusa. Niže funkcionalne sposobnosti imaju posljedice i veći rizik od raznih bolesti. Stoga ne postoji aktivnost poput sportskog treninga kako bi se spriječili potencijalni problemi.

Ključne riječi: *izvannastavne aktivnosti, tjelesna i zdravstvena kultura, funkcionalne sposobnosti*

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METHODS OF IMPLEMENTATION OF AN ALPINE SKIING SCHOOL

NAČINI PROVOĐENJA ŠKOLE ALPSKOGA SKIJANJA

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ABSTRACT

Nowadays, various programs are used in ski schools to teach beginners. All programs have the same goal, and that is to teach beginners specific body movements with which they will be able to manage their skis. Three programs are most commonly used in alpine skiing schools. According to one program, ski beginners are taught the basics of alpine skiing exclusively with elements of parallel skiing techniques. In the second program, ski beginners acquire knowledge using elements of snowplough and parallel ski technique. The third alpine skiing learning program combines these two methods. In addition to the program, in practice there are two approaches to learning alpine skiing. The first method involves a daily trip to a ski slope or a nearby winter tourist centre, where the skiing technique is adopted and beginners return to the place of residence the same day. The second way consists of an organized, usually seven-day, winter trip, during which the basics of alpine skiing are learned every day during the stay in the ski-resort. Regardless of the learning programs used, the safety of skiers is a priority in every alpine skiing school. Therefore, it is advisable for all beginner skiers to get involved in an alpine skiing school, as this is the best way to prevent injuries.

Key words: *programs, skiing school, direct learning, traditional learning, combined learning.*

METHODS OF IMPLEMENTATION OF AN ALPINE SKIING SCHOOL

INTRODUCTION

For many years alpine ski schools in winter tourist centers were the only content organized and offered in the mountains during the winter. Alpine skiing schools are still organized and implemented in all ski centers, but the offer of various physical and entertainment activities has expanded significantly. Alpine ski schools have adjusted their programs, and today they organize and implement ski kindergartens for the youngest beginners, individual and group programs for different levels of ski knowledge, morning or all-day ski schools, one-hour or multi-hour lessons, snowboard schools, ski school and teacher's snowboard school. on and off groomed ski-slopes (freeriding, free skiing, ski safari, freestyle) and learning different types of jumps in snow parks. Snow parks are extremely popular today among young skiers who want to engage in attractive acrobatic ski jumping and are therefore an integral part of most ski resorts.

Application of alpine skiing school in practice

There are two most common ways to learn alpine skiing. The first way involves going daily to the ski slope or the nearby winter tourist center, where the skiing technique is learned, and then returning to the place of residence in the afternoon or evening. The ski polygon is usually described as a natural or artificial ski terrain that exists independently and is not part of the winter tourist center. In addition to the terrain, every ski slope has a machine for its arrangement and maintenance, safety nets and signs that serve for protection and safety. Additionally, the ski slope has a ski lift, snowmaking devices and very often lighting, which allows the use of the terrain in the late afternoon and evening. Ski halls are also counted as ski slopes, and are often built near settlements and cities. Although they do not yet exist in Croatia, in many European countries alpine skiing schools exist in such places. The advantage of the ski hall is the possibility of its use throughout the year, and not only during winter. Additionally, an advantage of the ski hall is the possibility for beginners to learn to adapt to the skis and move on them in the immediate vicinity of the place of

residence. Once they learn the basics, they can decide to travel to a winter tourist center, where the overall experience of the idyllic mountain environment during the winter will be greater, because they will be able to use the ski terrains to a greater extent.

Another way is to organize the departure of children and young people for the winter holiday with school or winter sport camp with the club. In the selected winter tourist center, winter holiday is usually organized for seven days, while sport camps could last for longer period of time. In this way, in addition to the acquisition and improvement of ski knowledge, it is possible to carry out sports training and other physical activities during the day, and social and entertainment activities in the afternoon and evening. (Cigrovski, Matković et al., 2019).

The main goal of the first method is to learn alpine skiing, while the goals of winter holidays and sports camps, in addition to the acquisition of ski knowledge, are also focused on other sports and on the socialization of children. Thus, during the implementation of winter holiday in children's curriculum, the following are affected: motor, functional, cognitive, emotional and social abilities and characteristics (Rausavljević et al., 2012). By spending time together during the winter, the children are constantly socializing and solving tasks during the day. The role of the kinesiologist between all activities is to encourage children to be independent, to motivate them and to be a role model for them with own behavior. Alpine skiing school is just one of the contents of winter holiday or sports camp to which many other values are attached, which ultimately positively affect the growth and overall development of children (Pišot & Vidamšek, 2004; Cigrovski, Matković et al., 2019).

Alpine ski school programs

There are numerous programs for ski beginners in alpine ski schools. However, the goal of each program is to teach beginners the specific body movements (ski movements) that are necessary for ski management and that participate in different proportions in performing all types of turns (LeMaster, 2010). The efficiency of the learning process will be higher if the program of the ski school is modified to the conditions in which the ski knowledge is transferred and the age and

abilities of the students. Additionally, in order for ski beginners to improve their knowledge of skiing, they need adequate ski equipment, appropriate ski terrain and a teacher who will modify a certain program to match their abilities and motivation. The programs are designed in a way that ski knowledge is gradually acquired, and each learned element of ski technique is a logical upgrade of already acquired knowledge with the ultimate goal of learning different types of parallel turns (Cigrovski & Matković, 2015).

The program of the ski school defines what will be done every day within the time estimated for the acquisition of ski knowledge. The program of an alpine ski school, according to which it is advised to teach beginner skiers, but also to improve the knowledge of more advanced skiers, has been defined and approved by the competent organizations. When compiling a six-day or seven-day ski school program, only one part of the entire official program needs to be selected. What part of the program will be used depends on: duration of the ski school within each day, number of teaching days, age of the students, their abilities, motivation and prior ski knowledge. The programs of the alpine skiing school change over time in a way that individual parts of the elements of skiing technique are performed in a slightly different way. Likewise, changes in the program are manifested in the advancement of an important methodical exercises to the level of an element of technique or the degradation of a particular element of technique to the level of a methodical exercise. Therefore, the programs may differ in the name of individual elements of the technique or in the recommended methodological exercises.

By reviewing literature, it is possible to highlight several of the most common alpine skiing learning programs. First learning program contains exclusively elements of the parallel ski technique. With such an approach, skiers are immediately taught to perform parallel turns, so this method is called direct learning (Murovec, 2006). This approach is more dynamic, and beginner skiers are mastering a gentle ski slope through methodical exercises and tasks in which the skis are constantly in a parallel position. Second learning program involves the use of elements of snowplough and parallel skiing, and this method is called the traditional way of learning (Lešnik & Žvan, 2010). The snowplough turn is the first continuous turn that ski beginners must achieve when learning this program. There is also a third

program of learning alpine skiing, which involves a combination of these two methods, so it is often called a combined approach to the transfer of ski knowledge (Lešnik & Žvan, 2010).

The second mentioned way of learning alpine skiing, whose programs contain elements and exercises of snowplough and the parallel ski technique, is mostly used in practice. The snowplough position of the skis in which the front ends of the skis (tops) are almost connected, and the rear ends of the skis (tails) are spread, ensures for the beginners a stable equilibrium position due to increased surface of the support on the snow surface. In addition to the stable position, the snowplough position allows the skier to control the movement speed. Controlled descent down the ski slope is provided to the skier when he pushes forward and inwards at the ankles, knees and hips in a snowplogh position to bring the skis to their inner side edges (Matković et al., 2004).

Due to all mentioned advantages of the snowplough position of skis for beginners, today the elements of this ski technique are very often applied in alpine ski schools. However, this doesn't mean that it is necessary to insist on a long-term retention of skiers in the snowplough position. On the contrary, after skiers have mastered their first turns using the snowplough ski technique, the execution of turns should be continued with elements and exercises which include parts when the skis are in a parallel position. The ski school program designed in this way is based on the ratio of the snowplough and the parallel part of the turn. The gradual transition from the snowplough to the parallel turn is learned from the end of the turn to its beginning. By reducing the part of the snowplough turn, skiers learn to perform an increasing part of the turn using a parallel ski technique.

This means that initially only the final part of the turn will be performed in a parallel position, then the most part of the turn in a parallel position, until finally the student does the whole turn with the skis in a parallel position. When the student is able to perform the whole turn with the skis in a parallel position, we can begin to learn how to use ski poles at the beginning of each turn (Tate, 2007). Which of the above methods to use primarily depends on the choice of the kinesiologist. Also, the selected method depends on the conditions in which skiing is being learned.

The conditions in the ski centers are different depending on the choice of ski terrains and the availability of ski

equipment, and ski schools within each center have adopted to the elements described above.

CONCLUSION

Alpine ski school for beginners and recreational level skiers is the best injury prevention. The safety of recreational skiers and the protection of their health is a priority in every organization of an alpine ski school. Therefore, it is advisable for all beginners and skiers with little experience in alpine skiing to get involved in a ski school to learn how to properly manage their skis, and to protect their health. In self-learning, wrong movements are often adopted and it afterwards requires a great effort of a recreational level skier to correct such movements. Skiing knowledge will be learned much easier and with less effort if the student from the start adopts proper body movements and if he practices those movements from the beginning while performing ski turns.

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SAŽETAK

Danas se u skijaškim školama primjenjuju različiti programi po kojima se uče skijaški početnici. Svi programi imaju isti cilj, a to je naučiti početnike specifične pokrete tijela pomoću kojih će moći upravljati skijama.Tri se programa najčešće koriste u školama alpskoga skijanja. Po jednom programu skijaške početnike se uči osnovama alpskoga skijanja isključivo elementima paralelne skijaške tehnike. Drugim programom skijaški početnici usvajaju znanja pomoću elemenata plužne i paralelne skijaške tehnike. Treći program učenja alpskoga skijanja kombinira navedena dva načina. Osim programa, u praksi postoje dva pristupa učenja alpskoga skijanja. Prvi način uključuje svakodnevni odlazak do skijaškog poligona ili obližnjeg zimskog turističkog centra, na kojemu se usvaja skijaška tehnika te se isti dan vraća u mjesto stanovanja. Drugi način sastoji se u organiziranom, najčešće sedmodnevnom, odlasku na zimovanje u sklopu čega se svaki dan uče osnove alpskoga skijanja. Neovisno o korištenim programima učenja, sigurnost skijaša prioritet je u svakoj školi alpskoga skijanja. Stoga je savjet svim skijašima početnicima uključiti se u školu alpskoga skijanja, jer na taj način čine najbolju prevenciju nastanka ozljeda.

Ključne riječi: *programi, škola skijanja, direktno učenje, tradicionalno učenje, kombinirano učenje*

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THE USE OF ELECTROMYOGRAM IN FOOTBALL SYSTEMATIC REVIEW

PRIMENA ELEKTROMIOGRAFA U FUDBALU PREGLEDNO ISTRAŽIVANJE

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ABSTRACT

The aim of this systematic review was to indicate and discuss the use of electromyogram in football. For the literature review, following electronic databases were used: Google School, PubMed, Medline and Mendeley for the period from 2005. to 2019. 20 papers were selected for this systematic review based on the established criteria. These studies focused the most on researching the following muscles: m.musculus quadriceps, m.biceps femoris, m.gastrocnemius, m.tibalis anterior and m. gluteus maximus. The review has determined quite a heterogenic choice of topics when it comes to the use of the electromyogram (herein after referred to as: EMG) in football, so the obtained results were grouped based on the similar characteristics. Therefore, the results were categorized according to the following topics: acute effects of the specific football activity, impact of the football strength training, training of kicking on the ball, results based on the difference in sexes, while the rest of the results were sorted in the joint group. Summarizing of the obtained results provides the insight in the multiple possibility for use of EMG in football in order to develop high quality analysis of the neuro-muscle activation of a certain muscle regions of the football players.

Key words: *EMG, electromyogram, muscles, soccer, football*

INTRODUCTION

Even though the first dates related to the EMG date from the 17th and 18th century, Dr. Lambert is considered to be the inventor or "father" of the EMG, as in the beginning of the 60s of the last century, together with his colleague Schmidt, he developed a machine to analyze electric impulses which was relatively user friendly (Reaz, Hussain, & Mohd-Yasin, 2006). Further development was enabled with the development of the computer technologies in the last 20 years, which enabled EMG system to be developed in today's form and functionality. Electromyography represents an electro physiological method of registering the action potentials of muscle motor units and of researching the conductivity of sensor and motor peripheral nerves (Đuriæ, & Mihaljev-Martinov, 1998). In other words, EMG represents a record of the special and temporal forms of the electric activity in the activated motor units, and has been considered the golden standard for a long time now when it comes to researching of neuromuscular functions (Farina, Merletti, & Enoka, 2004; Kinugasa, & Akima, 2005). General characteristics of the surface EMG, namely its amplitude and strength spectra, depend on the characteristics of the muscle fibers membrane, as well as on the time of the muscle potential activity. This way, the surface EMG reflects both peripheral and central characteristics of the neuromuscular system (Farina, et al., 2004). The improvement of the EMG devices for detection of the electric potentials of performed willing complex movements and the evolution of the methodological approaches to data collection, as well as the computer analysis of patterns, are responsible for higher and higher use of EMG in bioengineering, rehabilitation, sports, as well as in the fields of biomechanics, physiology, zoology and ergonomics (Clarys et al., 1988). Monitoring performances of the elite athletes is vital to achieving better competition results (Hernandez, Estrada, Garcia, Sierra, & Nazeran, 2010). Kinesiological electromyography researches can be summed up in a following way: studies related to the normal muscle function during the selected moves and postures; studies of the muscle activity in complex sports, studies related to rehabilitation and athletes' recovery; studies researching the isometric contractions with the increase of muscle tension; studies researching functional anatomic muscle

activity (validation of the classical anatomical functions); studies of coordination and synchronization (kinematic chain); studies related to the specifics and efficiency of a certain training methods; studies researching muscle durability and the impact of fatigue; studies researching relation between electromyography and human muscle strength etc. (Clarys, 2000).

It is well known that EMG is mostly used in medicine and related areas, which explains why the majority of electromyography related studies is connected to the medicine. Nevertheless, contemporary sports, especially in the last 2 to 3 decades has been "leaning on" the medicine and related areas, leading to realizing the benefits from the EMG in sports as well, and finally leading to the multiple use of EMG in sports. Based on these findings, it can be assumed that football can obtain benefits from the research in the area. Therefore, the aim of this systematic review is to indicate the impact of use of EMG in football.

METHODOLOGY

Resources and strategy

For the literature review, the following electronic databases were used: Google Scholar, PubMed, Medline and Mendeley for the period from 2005. to 2019. The following key words were used for the research: EMG, electromyogram, football, soccer. Research strategy was customized for each electronic base in order to increase sensitivity. All titles and abstracts were reviewed, as well as the reference lists from the previous systematic reviews and original researches. Relevant studied were selected based on the following criteria:

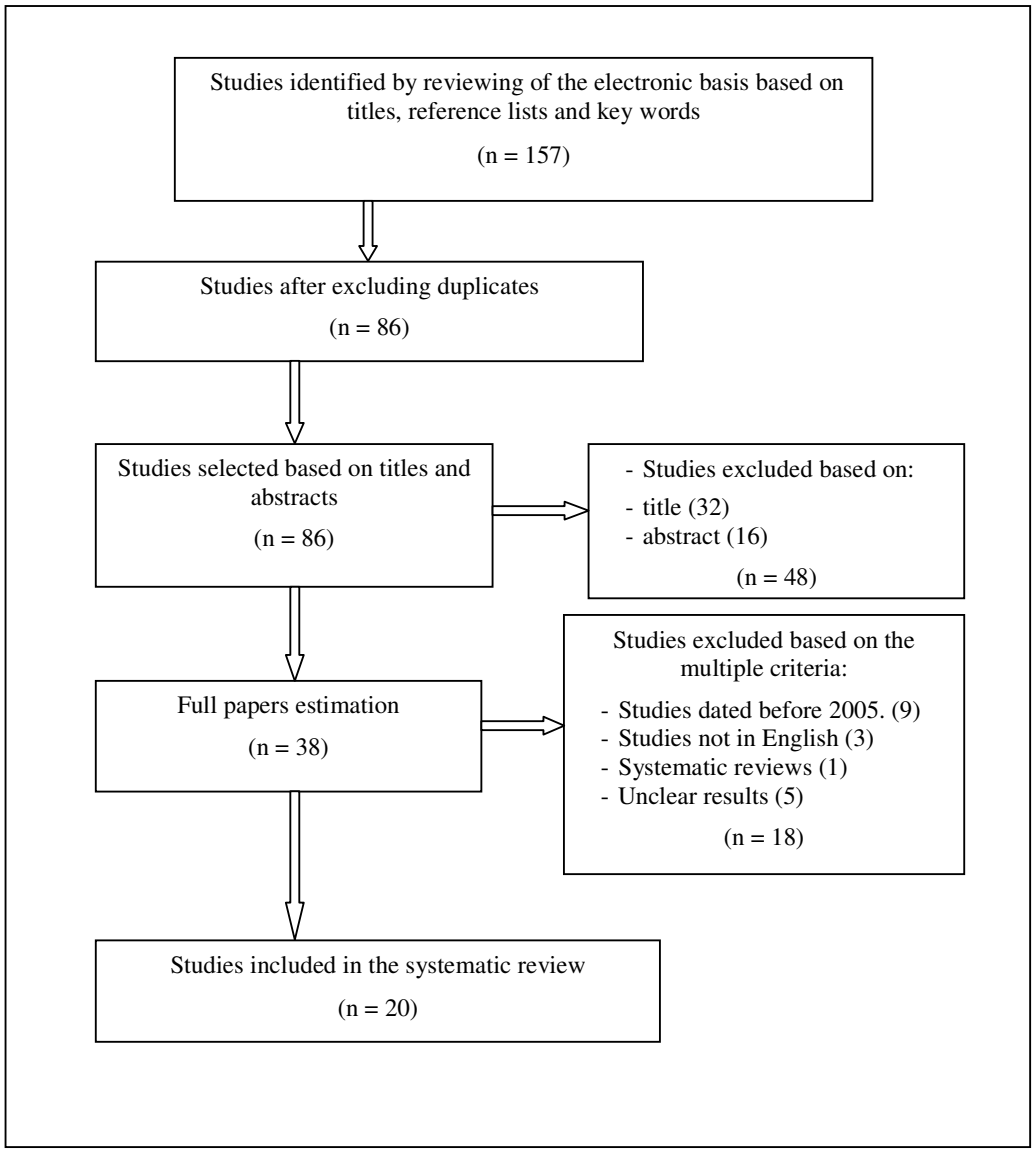
Criteria for including the study:

- Studies that included research of muscle potential of football players using EMG
- Studies in English
- Studies published between 2005. and 2019.
- Studies that are not full papers

Criteria for excluding a study:

- Studies written in languages other than English
- Studies dated before 2005.
- Studies that are not full papers (only abstract)
- Systematic reviews
- Studies in which obtained results are not presented clearly
- Duplicates

Scheme no. 1: *Diagram of the studies' analysis process*



RESULTS

Table 1. *Systematic review and characteristics of the studies included*

First author and year	Sample	Sex	Age	Sample size (n)	Research topic	Muscles examined	Examined EMG character.	Results	Conclusion
Kaygusuz, et al. (2005)	E1: F E2: B + H CG: SE	M	19, 9	30	Effects of various trainings on the neuro muscle activation	GCL GCM APB	AMP AR FR HRT	E1: AMP GCL↑, GCM↑ (p<0.05), AMP GCL↑, GCM↑ (p<0.05); E2: AMP GCL↑, GCM↑ (p<0.01), AMP GCL↑, GCM↑ (p<0.01), FR (p<0.05), HR (p<0.05)	Volleyball and basketball trainings contribute to neuro muscular differences and differences in upper and lower extremities more than football trainings, as both extremities are highly used in these sports
Greig, et al. (2006)	E: F	M	24, 7	10	Examination of the response of internment treadmill protocol based on the national analysis of matches played	RF BF	EMG peak total	HR INT↑ (p<0.01); RPE INT↑ (p<0.01); SS INT↑ (p<0.01); BF total INT>SS (p<0.01); BF peak INT>SS (p=0.05); RF total INT>SS (p<0.01); RF peak INT>SS (p<0.05);	INT activity profile induces cumulative mechanic load of the muscular skeleton system. Increased injury incidence in final phases of the match can be connected with the disturbed mechanics of movement, and not with the physiological stress.
Manolopoulos, et al. (2006)	E: F CG: F	M	20, 8	20	Impacts of combination of strength training with kicking on the ball on the biomechanics of football shoot in amateur	RF BF VM GCM	MVC	TI and MVC CoM↑ (p<0.05); LV↓(p<0.05); AV↑(p<0.05); EMG BF↑ (p<0.05); MVC VM↑ (p<0.05); Fmax↑ (p<0.05); 10m↑ (p<0.05)	Training had no effect on the EMG values, except decrease of the average value of GCM, while the maximum isometric strength and sprint time were significantly increased after the training. Results indicate implementation of the specific football program of strength exercises is especially efficient in improvement of performances of the football shoot.
Rahnmana, et al. (2006)	E: F	M	21, 4	10	Electromyography of lower extremities muscles fatigued by the intensity of the football match	RF BF TA GCM	MVC	MVC after 45 and 90' RF↓, BF↓, TA↓ (p<0.05)	Results indicate that, after the simulation of the intensity of football game exercises, EMG activity in bigger muscles of lower extremities was lower than before. This decrease indicates that extended exercising impacts muscle activity, even if a working rate is

									maintained.
Brophy, et al. (2010)	E1: F E2: F	M+ FF	19, 6	25	Differences between sexes in activation of lower extremities muscles while kicking on the ball with leg	VM VL GC GM A GME IL HM	MA swing and standing.	Swing IL 123%M>34%FF (p=0.0007); standing VM 124%M>55%FF (p=0.005); GME 113%M>69%FF (p=0.002); GMA 139%M>78%FF (p=0.07)	Differences in sexes in harmonizing lower extremities and muscle activation occur during the football side leg kicks. Decrease activation of the hip arresters and increase activation of the hook receivers in the supporting limb during the football kick can be connected with the increased injury risk of the anterior cruciate ligament.
Hart, et al. (2007)	E1: F E2: F	M+ FF	19, 7	16	Differences between sexes in the GME muscle activation during the long jump in football players	GME GC M VL LHM	MA	GME M 7.16>2.62 FF (p=0.002)	Average GME muscle activity was significantly higher in men than in women, while no differences between sexes related to other muscles.
Oliver, et al. (2008)	E: JF	M	15, 8	10	Changes in parameters related to jump and muscle activation after the specific football exercises	VL BF TA SO	MA	MA during DJ: VL↓, BF↓, TA↓ (p<0.05); SO↑(p<0.05); SJ -1.4 (p<0.05); CMJ -3.0 (p<0.05); DJ -2.3 (p<0.05); MA & CMJ (p=0.07), MA & DJ (p<0.05)	Results indicated that performance in all jumps was decreases after the specific football activities. Decrease of muscle activity was the highest regarding the in depth jump, which indicates the impact of muscle flexibility, and stress on the decreases muscle activity when muscles are fatigued.
Beaulieu, et al. (2009)	E1: PF E2: PF	M+ FF	22, 0	30	Differences between sexes in EMG parameters time-frequency of the unforeseeable maneuvers	RF BF TA GC M VL+M ST	EMG IC TI	EMG M=FF ST, GCM, GCL (P>0.05); IC M>FF for VL (P= 0.011, d= 0.99), VM (P= 0.010, d= 1.01) and during the phase VL (P= 0.002, d= 1.23), RF (P= 0.025, d= 0.86) and VM (P= 0.005, d= 1.13); TI-peak earlier in FF than in M for BF (P= 0.026,d= 0.86); and later for TA (P= 0.003, d= 1.21)	Female athletes adopt a different strategy of the recruitment of motor units, which is especially visible in IC, which results in the higher frequency of the EMG LHM signal. This strategy may explain the differences between the sexes in the injury rate of ACL. Differences in sexes in kinematics of the knee joint were noticed, followed by the exposing of female ACL to higher effort, which can be a results of differences in neuro muscular strategies in stabilization of the knee joint.
Thorlund, et	E: JF	M	17, 6	9	Change of the fast muscle	QD HM	EMG MVC	MVC↓ 10 % (p ≤0.01); RFD↓	Decrease of the fast muscle strength was

al. (2009)					force during the football match		RFD	9% (0 – 200 ms); VL 17%, BF↓ 31% ($p \leq 0.05$)	noticed, which probably negatively impacts performances of explosive activities (namely, acceleration, hitting, sprint) which are a part of football matches.
Cerrah, et al. (2011)	E1: PF E2: F	M	22, 9	31	Activation characteristics of knee muscles of the shooting leg during the shoot compared to the parameters of the isokinetic strength and ball speed	RF BF VM VL GC	MVC 800ms before and 800ms after the shoot	E1< E2 190−380 ms RF ($p<0.05$); E1>E2 200−620 ms VL ($p<0.05$); E1<E2 470−580 ms VM ($p<0.05$); E1>E2 650, 600, 100, 50ms BF ($p<0.05$); E1<E2 250−400ms GC ($p<0.05$)	Findings of this study, based on the EMG, indicate that the performance of professional players, compared to amateur players, is not connected to the strength factor, nut to the subtle differences in technique, related to the precision itself.
Amori - Khobasari & Kellis (2013)	E: F	M	18, 8	12	Impact of static and dynamic flexing on the neuro muscle components during the shoot	VM VL RF	MA	E: F dynamic. EMG RF↑ ($p=0.015$), VL↑ ($p=0.004$), VM↑ ($p=0.049$), AV↑ ($p<0.001$); static EMG RF↓ ($p=0.015$), VL↓ ($p=0.004$), VM↓ ($p=0.049$), ↓ ($p<0.001$)	Based on the obtained results, it can be suggested that dynamic flexing is more efficient in increasing upper knee muscle activation, as well as related to the angle speed in the knee joint extension during the final phase of shooting of the ball.
Chauhan, et al. (2013)	E: SPF	M	24, 4	15	Muscle architecture prediction based on the isometric contractions	VL RF	MA UP	UP& EMG RF ($R^2=0.68$, $p<0.005$); UP & EMG VL ($R^2=0.40$, $p>0.05$)	Results indicate strong relation between EMG muscle activation and muscle strength. These findings suggest that EMG base measures can be used for forecasting of the muscle strength and that ultrasound based measures can be useful in forecasting EMG muscle activity, This is interesting, as these two tools of the ultrasound measure different aspects of muscle function.
Katis, et al. (2013)	E: F	M	23, 7	21	Muscle activation of the shooting leg during the precise and unprecise shoots	RF BF TA GC	MA	PR upper TA↑ ($p=0.026$), BF↑ ($p=0.043$), GC↑ ($p=0.040$); lower TA↑ ($p=0.041$), RF↑ ($p=0.041$)	Players who demonstrated higher activation of TA and РΦ muscles may be less precise. It has been concluded that the activation of the shooting leg muscles represents a significant mechanism which highly contributes to the precision of the football shoot.

Oliver, et al. (2014)	E: JF	M	15, 8	10	Changes in neuro muscular control leg stiffness after the specific football activities	VL BF TA SO	MA MS	MS (26.6 vs. 24.0 kN·m-1, p > 0.05), CoM dis. (r = 0.90, p < 0.01), GRF (r = 0.58, p > 0.05); MA SO (r = 0.64, p < 0.05), VL (r = 0.98, p < 0.05)	After physical exercises, certain changed in the activation of extensor muscles modulate the change in moving the mass center and in stiffness of the leg muscles. Certain changes which decrease pre activation, stopping activity and, consequently, stiffness in muscles of the leg followed by fatigue can increase the risk of injury.
Serner, et al. (2014)	E: PF	M	21, 4	40	EMG evaluation of the hip adduction exercises in football players	AL GME RA EAO	EMG	AL with 14% on 108% EMG (p<0.0001); in 3 out of 8 exercises (35–48%, p<0.0001); RA with 5% on 48% EMG (p<0.001)	Hip adduction exercises with the elastic band can be dynamic high intensity exercises that can be easily performed in any institution and could, therefore, be relevant for including in future prevention and rehabilitation programs.
Girard, et al. (2015)	E: PF	M	27 ±1	17	Neuro muscle fatigue after the match in mild and hot climate	SO	MA MVC RFD	E: SO↓ -1.5% (p<0.05), PPT↓ -16.5% (p<0.05), F30↓, F50↓, F70↓ (p<0.05)	Changes in maximum willing activation of plantar inflexions were moderate and not different after the match in mild and hot weather conditions.
Campayo‐Piernas, et al. (2017)	E1: VIF E2: F C: VIS	M	24, 4	28	Role of eye sight in the instable balance tasks and difference between visually impaired and football players with healthy eye sight	RF PL TA GCL	EMG	PC1=53.96%, PC2=17.41%, PC3=12.77%; PC1 E2 EMG↓ (dg=0.72), K EMG↓ (dg=0.49), PC2 and PC3 no difference between groups	Regarding the neuro muscular behavior, 3 main patters explained 84,15% of total differences in gathered data, namely: PC1-size and shape of the activation amplitude pattern, PC2- relation between flexors and extensors, and PC3- relation between pronation and sub pronation. Improvement of other senses due to the visual imparity does not enable better balance of visually impaired players than healthy football players and visually impaired students when playing with closed eyes. Visually impaired players increase the muscle co activation as a safety strategy, but this behavior is no different from players with healthy eye sight when playing with closed eyes.

Schuerman, et al. (2017)	E: F C: F	M	24.3	51	Examination of the impact of the proximal neuro muscular control on the knee injury prevention	HM GMA TM	MVC	GMA↑ flight phase(P= 0.027); TM↑ flight phase (P=0.042); HM↓ pain with 20% on 6% (P<0.024)	It seems that muscle activity during the explosive running is connected with the hamstrings injury occurrence in football players. Better control of GMA and TM muscle activation during the plying phase in running, is connected with the lower hamstrings injury risk. Present results offer a base for the improvement of rehabilitation and prevention based on evidence, especially by focusing on the increase of the gluteus and abdominal muscles during sports activities.
Privalova, et al. (2019)	E: F	M		12	Testing of function of muscles included in kicking with the leg on the ball	VL VM GCL GCM	AMP FR	VLd>VLl, FR GCd>GCl (p<0.05), AMP GCl>GCd (p<0.05), VL & GM (p<0.05)	Sports training aimed at improving of the leg shooting technique of football players, contributes to forming of functional muscle complexes which participate in the axial rotation lodes and in lateral movement of the knee.
Read, et al. (2019)	E: F	M	28,2	10	Impact of the angle of the knee joint on the muscle activation of the back chain during the isometric test of football players	GMA BF ST GCM	MVC	MVC BF30º>BF90º (31%>22%, p<0.002); GMA (CV% = 36.1 vs. 19.8), GCM (CV% 31 vs.22.6)	90º angle indicated lower variations in performance, especially in gluteus maximus and medial gastrocnemius. Therefore, athletes who use test for the estimation of the leg strength, can give advantage to the 30º angle of the knee joint.

Legend: ACL - Anterior Cruciate Ligament; AL - m.Adductor Longus; AMP – amplitude; APB - m. Abductor Policis Brevis; AR – area underneath the curve potential; ÀV – Angular Velocity; B – Basketball Players; BF - m. Biceps Femoris; CV - Coefficient of Variation; CG – Control Group; CoM dis. - Center of Mass Displacement; DJ - Deep Jump; E (1-2) – Experimental Group; EAO - m. External Abdominal Oblique; EMG – electromyogram; F – Football Players; FF – Female Football Players; FR – Frequency; GCL - m. Gastrocnemius Caput Laterale; GCM - m. Gastrocnemius Caput Mediale; GMA - m.Gluteus Maximus; GME - m. Gluteus Medius; GRF - Ground Reaction Force; H – Handball Players; HM – Hamstrings; H-R - H-Reflex; HRT - Half Relaxation Time; IC - Initial Ground Contact; IL - m. Iliacus; INT – Interminent; JF – Junior Football Players; LHM – Lateral Hamstrings; LV - linear velocity; M – Male; MA – Muscular Activation; MS - Musculus Stiffness; MH - medial hamstrings; MV - M-wave; MVC - Maximal Voluntary Contraction; PC - Principal Component; PF – Professional Football Players; PL - m. Peroneus Longus; PTT - Peak Twich torque/force; QD - m. quadriceps; RA - m. Rectus Abdominis; RF - m. Rectus Femoris; RFD - Rate of Force/Torque Development; RPE - Rating of Perceived Exertion; SE – Sedentary Persons; SO - m. soleus; SPF – Semi - professional Football Players; ST - m. Semitendanosus; TA - m. Tibialis Anterior; TI - Approximation of the EMG Signal's Power; UP - Ultrasound Pennation Angle; TM - Trunk Muscles; VA - Voluntary Activation; VIF - Visually Impaired Football Players; VIS - Visually Impaired Students; VM - m.Vastus Medialis; VL - m. Vastus Lateralis.

DISCUSSION

This systematic review included 20 studies on EMG examination on football players. A total of 387 were included, average of 19 per study. The lowest number of participants was 9, and the highest 51. Examination of muscle activation in football players was mainly related to the lower extremities, and the focus was on the following muscles: m.musculus quadriceps (m.vastus lateralis et medialis 11, rectus femoris 10), m.biceps femoris 12, m.gastrocnemius 11 times, followed by m.tibalis anterior 6 and m. gluteus maximus et medius 6 times. The review has determined quite a heterogenic choice of topics when it comes to the use of the EMG in football players. Some of the studies analyzed acute effects of the football activities, while the others examined the impact on various training programs on muscle activity, as well as the muscle activation while shooting the ball. A lower number of studies examined injuries and causes of injuries, sex differences in muscle activation of football players and so on.

A couple of studies examined the acute effects of football activities. Results indicated that football specific activities caused a reduction in muscle activity (Girard, Nybo, Mohr, & Racinais, 2015; Oliver, Armstrong, & Williams, 2008; Oliver, Croix, Lloyd, & Williams, 2014; Rahnama, Lees, & Reilly, 2006; Thorlund, Aagaard, & Madsen, 2009), force increment rate and a decrease in explosive performance (Oliver, Armstrong, & Williams, 2008; Thorlund, Aagaard, & Madsen, 2009), even though the working rate remained the same (Rahnmana et al., 2006). Thorlund et al. (2009) determined that in the period after the match, a significant decrease in the muscle activation occurs VL for 17% and BF for 31% ($p \leq 0.05$) with an average reduction of QD and HM for 10%, with the decrease of RFD for 9% ($p \leq 0.01$), which negatively impacts the explosive activities. Rahnmana et al. (2006) detected a significantly lower activation of muscles RF, BF and TA after 45 minutes, and especially after 90 minutes football match ($p<0.05$). Differently from the regular match, Oliver et al. (2008) were observing the intermittently specific running that is at the same intensity as in the football match even after 43 minutes of running, the activation was lower in all of the jumps, especially in the in depth jump for muscles VL↓, BF↓, TA↓ ($p<0.05$). Authors determined the negative impact on the movement mechanics as well, leading to

the modulation of changes that decrease activation, activity related to the transfer of the mass center and to the stopping of the body (Greig, Mc Naughton, & Lovell, 2006; Oliver et al., 2014). Disturbed mechanics of movements as a consequence has the increase of injury risk in football players (Greig et al., 2006; Oliver et al., 2014). Girard et al. (2015) stipulate that the changes in the maximum willing activation are not different after the competition in mild and hot climate.

The rest of the studies that examined the impact of training were experimental. Football specific strength training led to the increase of the average EMG value in muscles GCM, BF and VM ($p<0.05$), while the maximum isometric strength and sprint time were significantly improved after the training ($p<0.05$) (Manolopoulos, Papadopoulos, & Kellis, 2006). Amiri-Khorasani & Kellis (2013) examined the impact of the dynamic stretching, which proved to be effective in increasing the upper knee muscle activation (VM, VL and RF) and the angle strength in knee joint extension while the ending phase of the shoot. While Serner et al. (2014) stipulated positive impact of training with elastic band on the hip injury prevention. After the hip flexion exercises there was a significant improvement of activation of muscles AL from 14% to 108% EMG ($p<0.0001$) and RA from 5% to 48% EMG ($p<0.001$) and significant improvement in 3 out of 8 exercises (35–48%, $p<0.0001$). The only study that compared football players with other athletes, detected significant increase of impulse amplitude of GCL and GCM muscles and in the group KO+OD and in football players, with the conclusion that in the end volleyball and basketball trainings contribute more to the neuromuscular differences in the upper and lower extremities (Kaygusuz, et al. 2005).

A couple of studies analyzed football shoot level of activation. Football training is aimed at improving the shooting technique as it contributes to development of the functional core muscles that improve football shooting performance (Manolopoulos et al., 2006; Privalova et al., 2019). While striking the ball with both legs, a higher activation of right leg muscle VL was detected compared to the left leg ($p<0.05$), while GC of the right leg had higher frequency, but lower amplitude than the GC of the left leg ($p<0.05$), followed by the established connection between VL & GM muscles ($p<0.05$) (Privalova, et al. 2019). Cerrah et al. (2011) have, by using EMG, established significant differences between professional and amateur athletes in the activation of muscles RF, BF, VM,

VL and GC ($p<0.05$), by proving that the difference was not based on the strength factor, except for the GCM muscle, but on the subtle differences in technique, related to the precision. Katis et al. (2013) stipulate that players who demonstrate higher muscle activation of TA and RF might demonstrate lower precision. Additionally, they noticed that activation of the shooting leg muscles significantly improves the shooting precision. Brophy et al. (2010) detected higher activation of standing leg in men, of VM, GME and GMA (VM 124% >55%, p=0.005; GME 113%>69%, p=0.002; GMA 139%>78% p=0.07) and IL (IL 123%>34%, p=0.0007) muscles of the stroking leg compared to women in sidekicks. This can be related to the higher risk of anterior cruciate ligament injuries in women.

A few studies examined causes of injuries in football players. Schuermans et al. (2017) examined muscle activity during the explosive running and its relation with the hamstrings injuries in football players. They concluded that the higher level of muscle activation of GMA (p= 0.027) and TM (p=0.042) during the flying phase is connected to the lower risk of hamstrings injuries. Greig et al. (2006) examined the causes of a decreased injury incidence in the final match phases and concluded that the main cause was a disturbed mechanic of movement, and not in the physiological stress. Looking at the sex differences, Beaulieu, Lamontagne & Xu (2008) stipulate that female athletes have a different strategy of motor units recruitment. There are significant differences in the lower frequency of EMG in the signal of the LHM muscle, as well as in the exposure of the ACL to higher load. No difference between men and women was found in ST, GCM, GCL muscle activation ($P>0.05$), higher activation was achieved in men in VL and VM ($P=0.01$), as well as in the whole duration of activation of VL, RF и VM. Women achieve maximum muscle BF activation significantly faster, and later of TA muscle compared to men. These information could play significant role in explaining ACL injury rate between sexes.

While examining differences between men and women football players in long jump muscle activation, a group of authors noticed that only the activation in the GME muscle (7.16>2.62, p=0.002) was significantly higher in men than in women, while no difference regarding any other muscle was found (Hart, Garrison, Kerrigan, Palmieri-Smith, & Ingersoll, 2007). In his study Beaulieu et al. (2008) found the difference only in the LHM muscle, while Brophy et al. (2010) determined higher activation of VM, GME

and GMA muscles of standing leg and IL muscle of striking leg in men. Authors did not look for a connection between previously mentioned parameters and football performance, but mainly researched their impact on occurrence of injuries. Listed sex differences could be related with the higher injury risk. The rest of the studies examined various topics so, for example, Campayo-Piernas, Caballero, Barbado, & Reina, (2017) examined differences between visually impaired football players and those with healthy eye sight. Even though they started the research with the premise that visually impaired players, due to visual limitations, have developed other senses, the study showed that it did not enable them better balance than players with healthy eye sight when playing with their eyes closed. Additionally, they determined 3 main patterns which explain 84.15% of the total number of changes in the neuromuscular behavior, namely PC1 (53.96%) - size and shape of the activation amplitude pattern, PC2 (17.51%) - connection between flexor and extensor, and PC3 (12.77%) – connection between pronation and supination. Chauhan, Hamzeh, & Cuesta-Vargas, (2013) detected strong relation between EMG muscle activity and muscle density. These findings suggest that measures based on EMG can be used for forecasting muscle strength, as well as that measurements based on the ultrasound can be useful for forecasting EMG muscle activation. A group of authors detected, by using the isometric squat test, that higher activation is achieved at the 30º angle flexion of the knee joint than at the 90º angle flexion of the back muscle chain that BF, GMA and GCM (Read, Turner, Clarke, Applebee, & Hughes, 2019).

Analysis of the results obtained so far confirm the thesis of Clarys (2000) that the areas of implementation of EMG in sports are very different. Namely, in previously mentioned cases, a couple of different research areas were segregated: acute effects of the football specific activity, football specific strength exercises, training of kicking on the ball, sex differences and so on. Based on the information provided, multiple use of EMG in football were indicated.

CONCLUSION

This systematic review was aimed at detecting multiple roles of EMG in football. Review included 20 studies that examined football players using EMG. Examination of muscle activation of football players was mostly related to the lower extremities, with the focusing on:

- m.musculus quadriceps
- m.biceps femoris
- m.gastrocnemius
- m.tibalis anterior
- m.gluteus

It was noticed that studies that examined muscle activation using EMG included very heterogenic topics, therefore by achieving various results. Achieved results were grouped by topics.

1) Acute effects of the football specific activities:

- decrease of muscle activity
- decrease of force increment rate
- decrease of explosive performances
- disturbing of the mechanic of movement
- reflecting on the working rate

2) Impact of football strength training led to:

- increase of average EMG value in GCM muscle
- improvement of the maximum isometric strength
- sprint time improvement

3) Training of kicking on the ball impacted:

- increase of football shoot performances
- subtle differences in shooting technique
- players with higher activation of TA and RF proved to be less precise
- no impact of the strength

4) Sex based differences:

- activity of GME was significantly higher in men than in women
- higher activation of VM, GME and GMA of standing leg in men
- higher activation of GMA and TM during the running flying phase in men

5) Other obtained results:

- dynamic stretching impacts the increase of MA and UB upper knee extensors
- exercises with elastic band impact the adductor injury prevention
- volleyball and basketball trainings improve neuro muscle differences more than football training
- visually impaired players do not have better balance than players with the healthy eye sight
- a strong relation between EMG activity and muscle strength was determined

Summarizing the obtained results provides and insight in the multiple purpose of electromyogram in football. Achieved results were grouped in common topics. Certain studies analyzed the acute effects of football activity, others examined the impact of different training techniques on muscle activity, as well as muscle activation while kicking with the leg. Lower number of studies examined causes of injuries, sex differences in muscle activation and so on. Based on the information provided, multiple use of EMG in football was detected. Moreover, a wide range of EMG use was confirmed, in order to provide clearer insight in the neuro muscle activation of football players.

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THE USE OF ELECTROMYOGRAM IN FOOTBALL SYSTEMATIC REVIEW

SAŽETAK

Cilj ove pregledne studije bio je da ukaže na primenu elektromiografa u fudbalu. Za pretraživanje literature korišćene su sledeće elektronske baze podataka: Google Scholar, PubMed, Medline, Mendeley u periodu od 2005. do 2019. godine. Nakon procedure selekcije radova u odnosu na odgovarajuće kriterijume, odabrano je 20 studija koje odgovaraju potrebama ovog sistematskog preglednog istraživanja. Mišići koji su najviše bili ispitivani su: m.musculus quadriceps, m.biceps femoris, m.gastrocnemius, m.tibalis anterior i m. gluteus maximus. Pregledom je uočen prilično heterogen izbor tema kada je u pitanju uloga EMG u fudbalu, pa su i njihovi ostvareni rezultati grupisani prema određenim karakteristikama. S tim u vezi rezultati su razvrstani prema sledećim temama: akutni efekti specifične fudbalske aktivnosti, uticaj fudbalskog treninga snage, trening udaraca po lopti nogom, rezultati u odnosu na polne razlike i ostale teme koje nije bilo moguće razvrstati u pomenute grupe. Sumiranjem dosadašnjih rezultata stiče se uvid u višestruku primenu EMG u fudbalu sa ciljem što kvalitetnije analize neuro-mišićne aktivacije.

Ključne reči: *EMG, elektromiograf, mišići, fudbal.*

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DETERMINING ASYMMETRY USING SPECIFIC UNILATERAL TESTS IN YOUNG BASKETBALL PLAYERS

UTVRĐIVANJE ASIMETRIJE PRIMJENOM SPECIFIČNIH UNILATERALNIH TESTOVA KOD MLADIH KOŠARKAŠA

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ABSTRACT

Defining the differences between the dominant (D) and non-dominant (ND) leg is one of the ways to determine the asymmetry between the extremities and thus the risk of injury. The aim of this research is to determine the differences in specific unilateral tests in young male and female basketball players. The sample consisted of 17 female basketball players (average height 177.96 ± 6.38 cm; average weight 69.53 ± 8.00 kg and age 15.50 ± 0.96 yr.) and 34 male basketball players (average height 194.29 ± 7.52 cm; average weight 83.66 ± 9.66 kg and age 15.40 ± 1.28 yr.) of the cadet and junior national teams. Tests were used to assess the explosive power of the lower extremities: high jump with D and ND leg take-off with arm swing (S_vis_jedn_L; S_vis_jedn_D), basketball two-step with D and ND leg take-off (Dvokorak_L, Dvokorak_D) and Drift protocol consisting of 5 consecutive unilateral jumps in place (Drift_L, Drift_D). The tests S_vis_jedn ($p = 0.02$) and Dvokorak ($p = 0.03$) showed statistically significant differences with an error of $p<0.05$ in the group of male basketball players. Significant differences were found in female basketball players in the test S_vis_jedn ($p = 0.03$). In other tests, there are no significant differences between jumps with D and ND leg take-off. The presented results indicate differences between the extremities and represent the basis for the correction of the training plan and program. The methodology in this paper is simple to implement and analyse and is aimed at imitating situational conditions.

Keywords: ***basketball, unilateral jumps, dominant and non-dominant leg***

INTRODUCTION

Basketball is a sport dominated by different types of jumps and landings. These structures are performed with maximum intensity and exhibit large forces in the joint systems (Kozinc et al., 2020). Therefore, it is necessary to focus on the characteristics of these activities, i.e., defining motor skills and knowledge. Determining the difference between a dominant (D) and a non-dominant (ND) leg is one way of defining asymmetry and the risk of injury. Jumps are a simple activity to assess power of the extremities. Also, these differences can be observed through some landing parameters after horizontal and vertical jumps (Edwards et al., 2012). Basic basketball tests of explosive power, agility and speed are regularly used to determine the level of motor skills (Ostojic, Mazic & Dikic, 2006; Wen et al., 2018). For a better understanding and exploitation of athletes' potential, it is necessary to focus on tests that imitate specific situations in the game with their characteristics and structures. Specific elements can provide better insights into the level of ability and parameters that are implemented in less controlled conditions. In the basketball game, the structures of movement in which the take-off with one leg (unilateral jump) dominates play a significant role. Unilateral jumps are highly associated with the ability to quickly change direction and the development of one ability can affect another and vice versa (Thomas et al., 2018; Maloney at al., 2017; Maloney et al., 2019). Rodriguez-Rosell et al. (2017) found a large association between two-leg jump from place (Abalakov jump) and unilateral jumps with a run-up from one (corr. 0.80-0.96) and two steps (corr. 0.88-0.98). Also, Sugiyama et al. (2014) found significant differences between the D and ND leg in the maximum horizontal jump with a run-up in senior basketball players. By applying specific tests, the movement structure is much more similar to situational conditions and can provide better data on the athletes' abilities and knowledge. Reduced physical abilities and large differences in jump height are indicators of increased risk of injury in young athletes in team sports (Fort-Vanmeerhaeghe et al., 2020). Shiltz et al. (2009) state that basketball players who have previously had one of the knee injuries retain an asymmetry ratio greater than 10% for all measured isokinetic variables and more than 15% of the

difference variables to assess unilateral functionality. These findings indicate the great importance of diagnosing the condition and determining the asymmetry between the extremities in order to timely influence the correction of motor skills and knowledge. By observing several types of unilateral jumps, it is possible to get an exact understanding of the shortcomings in the level of power of the lower extremities. The aim of this study is to determine the differences in specific tests between dominant (D) and non-dominant (ND) leg jumps in young male and female basketball players.

METHODS

Subjects

The sample consisted of 17 female basketball players (average height 177.96 ± 6.38 cm; average weight 69.53 ± 8.00 kg and age 15.50 ± 0.96 yr.) and 34 male basketball players (average height 194.29 ± 7.52 cm; average weight 83.66 ± 9.66 kg and age 15.40 ± 1.28 yr.) of the cadet and junior national teams. All subjects were in good health status at the time of testing. The dominant, that is the take-off, leg of all subjects was the left one.

Procedure

Measurements were conducted in a basketball court during the preparation period of the national teams. Prior to the start of the measurement, the subjects were introduced to the measurement protocol and performed a standardized warm-up consisting of running, track-and-field drills, dynamic stretching, and imitating of the elements performed in the testing. Tests were used in the study to assess the explosive power of the lower extremities: high jump with left and right leg take-off with arm swing (S_vis_jedn_L; S_vis_jedn_D), basketball two-step with left and right leg take-off (Dvokorak_L, Dvokorak_D) and Drift protocol of 5

consecutive unilateral jumps in place (Drift_L, Drift_D). The subjects were instructed to perform the test with maximum intensity in order to achieve the highest possible jump height. The tests were repeated 3 times and the best result was used for further analysis. The jump height in the tests was measured with an optical measuring instrument Optojump, Microgate (Glatthorn et al., 2011). Test description: *S_vis_jedn* - The initial position of the subject when performing unilateral jumps from the steps is outside the measuring space. At the examiner's signal, the subject performs one step from the place and a vertical take-off with a stepping leg inside the measuring space. The other leg serves as a swing. During the jump, a swing of the arms and a two-legged landing are used.; *Two-step* - the subject performs two steps from the place and in the second step he turns horizontally into a vertical movement with the help of the movement of the swinging leg and the swing of the arms; *Drift protocol* - 5 consecutive unilateral jumps are performed using the swing of the arms and swinging leg in order to achieve the maximum height of the jump and maintain an equilibrium position.

Statistical analysis

The measured results were analysed by the statistical program STATISTICA v13.5. Basic descriptive indicators (Min, Max, Mean, St.dev) were determined for all measured variables. A t-test for independent samples was used to determine the differences between the jump height with the D and ND leg take-off. The results were considered statistically significant at $p < 0.05$.

RESULTS

Table 1. *Descriptive indicators of the observed variables in specific jumps*

Variables	G	Mean	Min	Max	SD
S_vis_jedn_L	Male	41.61	31.60	51.50	5.04
	Female	31.09	23.40	39.00	4.33
S_vis_jedn_D	Male	38.63	29.40	51.00	4.89
	Female	28.16	21.50	33.50	3.34
Dvokorak_L	Male	46.56	35.90	59.90	5.70
	Female	35.51	27.70	43.40	4.37
Dvokorak_D	Male	43.39	34.60	57.70	6.11
	Female	33.18	25.40	39.00	4.15
Drift_L	Male	21.69	16.00	30.70	3.43
	Female	16.01	11.60	21.70	2.74
Drift_D	Male	20.93	14.80	27.40	3.29
	Female	15.16	10.40	20.00	2.77

Legend: G - gender; Mean – arithmetic mean; SD - standard deviation; Min - minimum value; Max - maximum value; S_vis_jedn_L - jump from a step with the left leg take-off; S_vis_jedn_D - jump from a step with the right leg take-off; Dvokorak_D - jump with a horizontal run-up of two steps and the right leg take-off; Two-step_L - jump with a horizontal run-up of two steps and the left leg take-off, Drift_L - consecutive jumps in place with the left leg take-off with; Drift_D - consecutive jumps in place with the right leg take-off

Table 1 shows the basic descriptive indicators of unilateral jumps. Average, minimum, and maximum values are higher in the male basketball players. The highest value of the jump was achieved in the test Dvokorak_L (59.90 cm). The lowest result of a unilateral jump was achieved in the Drift_L test (10.40 cm). The average values of the jumps in all tests were higher when the test was performed with the D leg take-off. The results in the two-step tests show the highest values compared to other tests performed. Also, in this test, the largest deviations of the results (5.70 cm) were found. The parameters of male basketball players in all tests deviated

more in relation to the female basketball players. There is a noticeable difference in the average jump height between the male and female group.

Table 2. *T-test for independent samples – MALE BASKETBALL PLAYERS*

Variables	N	t	F-ratio	p	difference
S_vis_jedn_L/D	34	2.47	1.06	0.02*	2.98
Dvokorak_L/D	34	2.21	1.15	0.03*	3.17
Drift_L/D	34	0.93	1.08	0.36	0.76

* marked values are significant with an error $p<0.05$.

Table 2, by using the t-test for independent samples, shows the differences in the jump height with the D and ND leg between the observed tests of the male basketball players. The tests S_vis_jedn ($p = 0.02$) and Dvokorak ($p = 0.03$) showed statistically significant differences with an error of $p<0.05$. In the Drift test, there was no significant difference between the D and ND leg ($p = 0.36$).

Table 3. *T-test for independent samples – FEMALE BASKETBALL PLAYERS*

Variables	N	t	F-ratio	p-value	difference
S_vis_jedn_L/D	17	2.21	1.68	0.03*	2.93
Dvokorak_L/D	17	1.59	1.11	0.12	2.33
Drift_L/D	17	0.90	1.02	0.37	0.85

* marked values are significant with an error $p<0.05$.

Table 3 shows the differences in the unilateral jumps of the female basketball players. Significant differences were obtained in the test S_vis_jedn ($p = 0.03$). In the Dvokorak ($p = 0.12$) and Drift ($p = 0.37$) tests, there were no significant differences between the D and ND jumps.

DISCUSSION

Fast and explosive basketball elements require highly developed and balanced athletes' abilities. Large differences in the power of muscles and muscle groups can negatively affect performance and risk of injury. The observed sample shows the difference in tests for estimating explosive power by using specific unilateral jumps. A statistically significant difference between the D and ND leg was found in male basketball players in the tests S_vis one ($t = 2.47$, $p = 0.02$) and Dvokorak ($t = 2.21$, $p = 0.03$). Pehar et al. (2017) also pointed out the differences in the jump height with the D and ND leg in the two-step test considering the playing position and rank of the competition. Also, in the test S_vis_jedn in the group of female basketball players, significant differences were found ($t = 2.21$, $p = 0.03$). The results of all male basketball players tests show higher values of jumps compared to female basketball players. Although no statistically significant differences were found in the remaining tests, they are present. In the S_vis_jedn version, there is a small horizontal speed, and it is necessary to create a large vertical force from the steps. Therefore, a higher level of power is required to achieve high values. The ratio of the jump height in the S_vis_jedn test (2.98 cm and 2.93 cm) indicates asymmetry and a reduced level of take-off ability with the ND leg. The largest difference was observed in male basketball players in the Dvokorak test (3.17 cm). No significant differences were found in the Drift test ($p = 0.37$ and $p = 0.36$). This test requires athletes to perform consecutive jumps with an emphasis on minimizing mediolateral and anteroposterior movement.

The largest difference (%) in the jump height was measured in the test Skok_vis_jedn (M = 7.2%, F = 9.4%). Larger differences in lower extremities asymmetry in female basketball players were also measured when performing different types of landings (Pappas and Carpes, 2012). The authors (Vaisman et al., 2017) suggest that if the difference between the indicators of muscle strength of the lower extremities is less than 15%, it is considered that there is no significant asymmetry between the D and ND leg. Also, Bishop et al. (2018) indicate that differences greater than 10% between the extremities negatively affect ability and

performance. The results of two-step with the D leg take-off in female basketball players can be compared with the findings of Keerthi Kumar and Sundar Raj (2016) that observed changes in the jump height of senior female basketball players before and after the program. The values of the jump height are almost equal (35.5 cm vs 35.6 cm), which means that it can be concluded that the observed sample of female basketball players achieves results equal to the senior category of female subjects. Comparing the results with the research of Miura et al. (2010), the presented sample of male basketball players has significantly lower height values in the Dvokorak and S_vis_jedn tests.

Long-term training in team sports can develop certain asymmetries between the extremities. Consecutive repetitions of movements with the D leg (unilateral jumps) negatively affect the balance of muscle strength. Unilateral vertical jumps can cause greater asymmetries between the extremities relative to different horizontal jumps (Fort-Vanmeerhaeghe et al., 2015). Lower ND leg values can also be explained through a low level of coordination and a reduced frequency of repetitions of jumps through the training process. By developing the jump technique through a 6-week training program, it is possible to increase explosive properties and vertical jump (7.5% increase) (Attene et al. 2015). According to Stöckel and Weigelt (2012), the gradual inclusion of different coordination tasks and sport-specific drills for the development of the ND side of the body is crucial to begin in as young a category as possible. Proper use of arm and leg swings directly affects the result, and in addition to the emphasis on equalizing the power of the extremities, attention should be paid to the method of performing jumps and landings.

CONCLUSION

Basketball is a sport dominated by different types of jumps. Reducing the risk of injury is one of the main reasons for conducting diagnostics of the athletes' condition and identifying their weaknesses. Differences in the jump height with the D and ND leg indicate the existence of strength inequality between muscle groups. The aim of this paper was to define these asymmetries by using unilateral specific tests. Statistically significant differences in the S_vis_jedn and Dvokorak tests were found in male basketball players. Also, the results of the female basketball players differed significantly in the S_vis_jedn test. In all tests, a difference was obtained between jumps with the right and the left leg take-off. The presented results indicate the presence of asymmetry and represent the basis for the correction of the training plan and program. This paper presents a simple methodology for determining asymmetry in abilities by applying tests that mimic situational conditions. The conducted research is focused exclusively on differences in jump height. By observing several jump parameters (contact time, ground reaction force, joint angles), the differences and potential risks in performing the jumps would be more precisely determined. Further research should focus on defining asymmetries between different categories of athletes in order to start with the correction of technique and equalization of abilities as soon as possible.

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DETERMINING ASYMMETRY USING SPECIFIC UNILATERAL TESTS IN YOUNG BASKETBALL PLAYERS

SAŽETAK

Definiranje razlika između dominantne (D) i nedominantne noge (ND) jedan je od načina utvrđivanja asimetrije između ekstremiteta a samim time i rizika od ozljeđivanja. Cilj ovog istraživanja usmjeren je na utvrđivanje razlika u specifičnim unilateralnim testovima kod mladih košarkaša i košarkašica. Uzorak ispitanika činilo je 17 košarkašica (prosječne visine 177,96 ± 6,38 cm; prosječne mase 69,53 ± 8,00 kg i dobi 15,50 ± 0,96 god) i 34 košarkaša (prosječne visine 194,29 ± 7,52 cm; prosječne mase 83,66 ± 9,66 kg i dobi 15,40 ± 1,28 god) kadetske i juniorske reprezentativne selekcije. Korišteni su testovi za procjenu eksplozivne snage donjih ekstremiteta: skok u vis iz koraka odrazom D i ND nogom sa zamahom ruku (S_vis_jedn_L; S_vis_jedn_D), košarkaški dvokorak odrazom D i ND nogom (Dvokorak_L, Dvokorak_D) i Drift protokol koji se sastoji od 5 uzastopnih jednonožnih skokova u mjestu (Drift_L, Drift_D). U testovima S_vis_jedn (p=0,02) i Dvokorak (p=0,03) prikazane su statistički značajne razlike uz pogrešku p<0,05 kod košarkaša. Kod košarkašica su utvrđene značajne razlike u testu S_vis_jedn (p=0,03). U ostalim testovima nema značajnih razlika između skokova odrazom D i ND nogom. Prikazani rezultati ukazuju na razlike između ekstremiteta te predstavljaju bazu za korekciju plana i programa treninga. Metodologija u ovom radu je jednostavna za provedbu i analizu te je usmjerena na imitaciju situacijskih uvjeta.

Ključne riječi: *košarka, jednonožni skokovi, dominantna i nedominantna noga*

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EFFECTS OF THE "SCHOOL ON THE MOVE" PROGRAM ON THE POSTURAL STATUS OF YOUNGER SCHOOL AGE STUDENTS

EFEKTI PROGRAMA „ŠKOLA U POKRETU“ NA POSTURALNI STATUS UČENIKA MLAĐEG ŠKOLSKOG UZRASTA

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ABSTRACT

In order to determine the effects of the "School on the Move" program on the postural status of students, a survey was conducted on a sample of 22 younger school age students of both sexes for the duration of one school semester. Students were given lectures on ergonomic risk and ways of reducing ergonomic risk factors, and a number of posters and flyers with proper lifting, bag-wearing and sitting techniques were distributed. The "School on the Move" ergonomic program encouraged students to move freely on their chair or to stand up and stretch when they experienced discomfort/pain, or perform a few brief stretching exercises while sitting on their chair. The postural status of the spine was assessed in the sagittal and frontal plane (thoracic and lumbar scoliosis, kyphosis and lordosis) by the "Spinal mouse" instrument (Quantum Health and Wellness Ltd, Wallasay, England). A repeated measures ANOVA was used for statistical data processing. The results showed that during the 16-week period, there was a significant improvement in the reduction of thoracic scoliosis ($p=0.003$) and kyphosis ($p=0.006$), while there were no significant changes in the lumbar scoliosis and lordosis. On the basis of these results, it could be concluded that such a program could have a significant impact on the posture improvement of the spinal column, and that it can be practically applied in the school curriculum as a preventive measure for spinal postural status disturbance of younger school age students.

Key words: *postural status, students, younger school age, "School on the Move" program.*

EFFECTS OF THE "SCHOOL ON THE MOVE" PROGRAM ON THE POSTURAL STATUS OF YOUNGER SCHOOL AGE STUDENTS

INTRODUCTION

Students spend most of their time at school at their desk. This should be a subject of interest for experts when designing furniture elements. This is a very responsible and difficult task for all actors, considering the fact that due to growth and development as well as continuous sitting, the body suffers the greatest static and other changes, which often leave long-term effects. It has been observed that the child's body is most influenced by the strict and absolute sedentary state which is not peculiar to children, whereby body fatigue and pain can occur in certain regions of the body, and longer sitting time leads to fatigue of the body (Weiss & Werkmann, 2009).

If sitting is done on inappropriate sized furniture or the body position cannot be altered, the effort is even greater. Many studies have shown that children complain about sitting at a desk, complain about discomfort and lower back, neck and upper leg pain, vision impairment and deconcentration (Castellucci et al., 2010; Grimmer & Williams, 2000). The main reason lies in poor or irregular posture, which is manifested by a relaxed posture, uneven shoulder height and a curved or hunched spine. In addition, recent studies in our country and around the world have shown that children spend more than seven hours of their active time sitting at a school desk and computer at home during the day, assuming a wide variety of forced body positions, adapting to the characteristics of furniture used everyday (Featherset al., 2013). Existing furniture that is actively used, both at school and at home, generally does not meet the needs of children (as well as adults), given the increasingly rapid and complex lifestyle rhythm imposed by modern lifestyles (Domljan et al., 2010).

A significant question regarding sitting in school for a long time concerns the incongruity between students and their workstations - the school desks and chairs (Grbac and Domljan, 2007). When an incongruity occurs, ergonomic stress will potentially increase. The anthropometric dimensions of the students' and the dimensions of the workstations (chairs and desks), define ergonomic mismatch. The incongruity occurs when multiple users of different age groups and body dimensions use unsuitable furniture of the same (universal) dimensions. Interestingly, much more effort is made towards providing ergonomically correct work equipment for adults (adjustable chairs, flexible work surfaces and appropriate furniture sizes). However, workstations for school children seem to be neglected as most classrooms are equipped with desks and chairs

of one size, regardless of the age of the students. This is a common policy, not only in our schools, but also in the region of the former Yugoslavia, primarily because of the lower purchase price, easier disposal, and similar aesthetic appearance of classrooms, but also because of insufficient knowledge of the anthropometric parameters of the school population and the lack of a domestic manufacturer of school furniture in concordance with ergonomic recommendations (Pavlović-Veselinović & Đurašković, 1995).

The main consequence of ergonomic incongruity is the adoption of bad sitting posture. When students of different heights sit on unsuitable chairs and desks, a high percentage of them will have difficulty while sitting. As a result, many children will compensate this by adopting non-physiological, uncomfortable body postures, potentially increasing biomechanical stress on the body. Ergonomic characteristics of school desks and chairs, and their influence on musculoskeletal structures, i.e. postural disorders of the spinal column, is an acute problem in school-aged children both at the global level and in our country, which alarms us to initiate all available resources and take steps to solve this problem. Each of these changes occurs as a consequence, in part of genetic factors, and very often as a result of acquired postural changes. Some of the mentioned factors have the greatest influence on postural status, such as the working environment, inadequate furniture, forced postures of the body when working or learning, inadequate lighting, etc. (Geldhof et al., 2007).

The ergonomic “School on the Move” program, which encourages students to move freely in their chair or to stand up and stretch during classes when they feel discomfort/pain or do a few short stretching exercises while sitting in a chair, is considered to be effective in preventing the occurrence of discomfort and pain while sitting, as well as postural disorders.

The aim of the study is to evaluate the effects of a specific "School on the move" ergonomic program, which is based on non-engineering preventive measures, consisting of the free movement of students during class in the form of short stretching exercises and getting up from their chair.

METHODS

The sample of participants was drawn from a population of students of the "Dušan Radović" Elementary School in Niš, chronologically aged 9-10 years. At the time of the survey, the participants met all the health and other criteria and had the status of full-time students whose parents gave written consent for their participation. The total number of participants included in this study is 22 students of both sexes (BH = 146.48 ± 4.80; BM = 40.91 ± 8.52).

The postural status of the spinal column was assessed in the sagittal and frontal plane (thoracic and lumbar scoliosis, kyphosis and lordosis) with the "Spinal Mouse" instrument (Quantum Health and Wellness Ltd, Wallasay, England), based on wireless ultrasound technology with the appropriate software (Livanelioglu et al., 2015; Zsidai & Koscis, 2001).

The experimental group of students were lectured on ergonomic risk and ways of reducing ergonomic risk factors, and a number of posters and flyers with the presented correct techniques for lifting and carrying a school bag/backpack and the correct way of sitting were distributed. The participants underwent the "School on the Move" ergonomic program, which included encouraging students to move freely on their chair or to stand and stretch during classes when they experienced discomfort/pain with a few short stretching exercises of their choice. Participants performed the exercises as needed with 10-12 repetitions while sitting on a chair or standing next to it. The entire training of the participants was practical with a demonstration of possible stretching exercises. The program was conducted over a period of 16 weeks.

Descriptive statistical procedures were applied to analyze the basic statistics and result distribution at the initial and final measurements. In order to analyze the changes in the results of the dependent variables between the initial and final measurements for each variable, a repeated measures analysis of variance (Repeated measures ANOVA) was applied. The significance of inference was determined at $p<0.05$. The data were processed with the statistical package STATISTICA 10.0 for Windows (StatSoft, Inc., Tulsa, OK).

RESULTS AND DISCUSSION

Tables 1 and 2 show the results of the postural status of the participants at the initial and final measurements, and in order to solve the problem of the effects of the "School on the Move" program effectively, it was necessary to determine the changes between the initial and final status of the musculoskeletal disorders (MSD) of the spinal column, following the experimental period. Using the repeated measures analysis of variance, the statistical significance of the differences in the arithmetic means of the initial and final measurements of the group were calculated, and the results are shown in Table 3.

Table 1. *Descriptive parameters of the **Postural status** variables of the students – initial measurement*

Variable	N	Mean	Std.Dev.	Min.	Max.	Range	Coef.Var.	Skew.	Kurt.	K-S
AKYP	22	38.50	7.15	25	55	30	18.6	0.47	0.34	0.09
ALOR	22	-10.00	8.91	-26	6	32	-89.1	-0.24	-0.92	0.22
ASCT	22	6.50	2.87	2	12	10	44.2	-0.03	-0.79	0.21
ASCL	22	1.23	1.19	0	5	5	97.2	1.56*	3.66*	0.26

AKYP – kyphosis; ALOR – lordosis; ASCT – thoracic scoliosis; ASCL – lumbar scoliosis; N – sample size ; K-S – Kolmogorov-Smirnov test value.

Table 2. *Descriptive parameters of the **Postural status** variables of the students – final measurement*

Variable	N	Mean	Std.Dev.	Min.	Max.	Range	Coef.Var.	Skew.	Kurt.	K-S
AKYP	22	33.86	8.35	22	51	29	24.6	0.52	-0.35	0.13
ALOR	22	-10.14	8.33	-24	5	29	-82.2	0.10	-0.94	0.12
ASCT	22	4.82	3.50	0	13	13	72.6	0.83	-0.05	0.15
ASCL	22	1.73	1.61	0	6	6	93.2	1.09*	0.89	0.22

AKYP – kyphosis; ALOR – lordosis; ASCT – thoracic scoliosis; ASCL – lumbar scoliosis; N – sample size ; K-S – Kolmogorov-Smirnov test value.

After analyzing Table 3., at the univariate level, it can be stated that statistically significant changes were observed in kyphosis and thoracic scoliosis, while there were no changes in lordosis. The changes are positive regarding both the kyphotic and thoracic scoliotic curves, which significantly decreased after the four-month experimental program.

Table 3. *Univariate differences between the initial and final measurements of the* ***Postural status*** *of the students*

Variable	Mean INI	Mean FIN	Difference	Difference %	F (1; 27)	p
AKYP	38.50	33.86	-4.64	-13.7	11.05	**0.003***
ALOR	-10.00	-10.14	-0.14	1.4	0.00	0.949
ASCT	6.50	4.82	-1.68	-34.9	9.28	**0.006***
ASCL	1.23	1.73	0.50	28.9	1.26	0.274

Mean INI– arithmetic means of the initial measurement; Mean FIN– arithmetic means of the final measurement; Difference – between the inital and final measurements; F – value of the F-test for assessing significance of arithmetic mean differences; p – significance of the differences.

In the discussion regarding statistical analysis of the results of this research, it can be concluded that the "School on the Move" program for the reduction of the spinal column MSD, contributed to a statistically significant reduction of thoracic spinal curves during the 16 weeks, while no changes were recorded in the lumbar section.

Considering the relatively small sample of participants (22), the statistical significance provides complete information about the level of MSD changes of the spinal column of the participants, but these changes are more clearly seen at the numerical level. Considering the significance of the effects of the applied program on the reduction of the MSD of the spine, it is important to state that every, even the smallest reduction in MSD, is essential for improving the quality of life of children, especially at the age when important and sudden changes of the muscular and skeletal system occur. This is important from an educational point of view of the children and parents, as the constant implementation of such programs contributes to the formation of a better final postural status of children.

For these reasons, it is important to report the numerically pronounced effects of the experimental program, especially those expressed in percentage numbers, where their practical contribution to the reduction of the MSD of the spinal column can be seen. The changes that occurred after the implementation of the "School on the Move" experimental program, expressed as a percentage, are significant in the thoracic section of spinal curves, both in the sagittal and the frontal plane. In kyphosis, a curvature decrease of 4.64 or 13.7% is observed, which is a high percentage of improvement, which is in accordance with the results of similar studies (Weiss &

Turnbull, 2010; Weiss & Werkmann, 2009; Djurasović & Glassman, 2007; Pizzutillo, 2004). The decrease in the thoracic scoliosis curvature is 1.68, or 34.9%, which represents a significant improvement in the reduction of poor postural status of children aged 11. These results are in agreement with the results of other studies (Negrini et al., 2008; Mooney & Brigham, 2003; El-Sayyad & Conine, 1994) that addressed the problem of reducing the scoliotic curvature of the spine.

CONCLUSION

Considering that the obtained results showed a positive impact of the "School on the Move" ergonomic program, it could be recommended to the Ministry of Education as an effective program for reducing ergonomic risk, one which does not require large financial investments until the conditions for production and procurement of newly designed school equipment are achieved. Newly designed school equipment must be aligned with the ergonomic requirements of the local child population, for which recommendations are also given.

The scientific contribution of this research is also reflected into the effectiveness of educating children about ergonomic risks and preventative exercises, as well as the concept of “School on the Move” in reducing the risk of musculoskeletal disorders in children, as no relevant data have been reported so far from this perspective. Indirectly, the research findings may contribute to the health of the future working-age population.

This research also has practical and theoretical value. First of all, there is a great need to pay attention to the development of children, and to provide them with the best conditions for their upbringing and education, while at the same time prevent the negative effects that are present in our increasingly accelerated social development, such as hypokinesia, obesity, spinal deformities, hypertension and more. Taking into account that there is a risk of developing musculoskeletal disorders, we especially emphasize the spinal column region, which suffers the greatest consequences due to the aforementioned conditions in our schools, so that during

childhood and adolescence, there may be a predisposition for the onset of serious musculoskeletal diseases in the working age of our population. It is necessary to prevent any postural changes from the earliest childhood.

A previous study indicates that musculoskeletal discomfort and lower back pain are evident not only in adults but also in children. Ergonomic education aimed at proper posture, improvement of body functions and certain movements, as well as their ergonomic implications, can reduce and prevent these problems. Such an educational program which implies the importance of ergonomics must begin at an early age and should be an integral part of the school curriculum. This research indicates that the "School on the Move" educational program, conducted at the “Dušan Radović” Elementary School in Niš, has produced extremely good results, which has pleased both the children, their parents, teachers and the school principal. This program showed that students of the Faculty of Sport and Physical Education, future professors, should implement postural disorder prevention programs, adjusting their work to the age characteristics of the children.

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EFFECTS OF THE "SCHOOL ON THE MOVE" PROGRAM ON THE POSTURAL STATUS OF YOUNGER SCHOOL AGE STUDENTS

SAŽETAK

Sa ciljem da se utvrde efekti programa „Škola u pokretu“ na posturalni status učenika, sprovedeno je istraživanje na uzorku od 22 učenika mlađeg školskog uzrasta oba pola u trajanju jednog školskog polugođa. Učenicima su bila održana predavanja o ergonomskom riziku i načinima za smanjenje ergonomskih faktora rizika i distribuiran je određeni broj postera i flajera sa predstavljenim ispravnim tehnikama podizanja i nošenja školske torbe/ranca i ispravnog načina sedenja. Ergonomski program „Škola u pokretu“ podrazumevao je ohrabrivanje učenika da se slobodno pokreću na stolici ili da ustanu i istegnu se tokom časova kada osete nelagodnost/bol i uz nekoliko kratkih vežbi istezanja, za vreme sedenja na stolici. Posturalni status kičmenog stuba je procenjen u sagitalnoj i frontalnoj ravni (torakalna i lumbalna skolioza, kifoza i lordoza) instrumentom „Spinal mouse“ (Quantum Health and Wellness Ltd, Wallasay, England). Za statističku obradu podataka primenjena je analiza varijanse za ponovljena merenja (Repeated measures ANOVA). Rezultati pokazuju da je u periodu od 16 nedelja kod učenika došlo do značajnog poboljšanja vrednosti torakalne skolioze (p=0.003) i kifoze (p=0.006), dok kod lumbalne skolioze i lordoze nije bilo značajnih promena. Na osnovu ovih rezultata se može zaključiti da ovakav program može imati značajan uticaj na poboljšanje posture kičmenog stuba, te se može primeniti u praksi školske nastave i kao preventiva narušavanju posturalnog statusa kičmenog stuba učenika mlađeg školskog uzrasta.

Ključne reči: *posturalni status, učenici, mlađi školski uzrast, program „Škola u pokretu“.*

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COMPARISON OF METHODS FOR DETERMINING PERCENTAGE OF BODY FAT ON A SAMPLE OF KAYAKERS AND CANOEISTS – IN SLALOM

KOMPARACIJA METODA UTVRĐIVANJA POSTOTKA MASNOG TKIVA NA UZORKU KAJAKAŠA I KANUISTA SLALOMAŠA

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ABSTRACT

Determining body structure in physical culture, sports, but also in sports recreation is one of the ways to check effectiveness of certain training programs and their impact on a percentage of subcutaneous fat and fat-free components. This study was conducted on a sample of 49 kayakers and slalom canoeists (aged 19.9 ± 1.7 years), and the aim was to compare validity of methods for estimating percentage of body fat based on the skinfold measurement method in relation to the bioelectrical impedance method for application in diagnostics within a training process of slalom kayakers and slalom canoeists. The percentage of body fat was determined by methods of determining the percentage of body fat according to Siri (1961), Brozek et al. (1963), Jackson, & Pollock, (1985) and the BIA bioelectrical impedance method. After statistical procedures, correlation analysis revealed a high correlation between the methods: anthropometric methods according to Siri and Brozek, both methods with the Jackson Pollock method, while all three methods have a high level of correlation with the BIA method, while the Wilcoxon test showed that the bioelectrical impedance method had statistically significantly higher values than the method of determining the percentage of body fat according to Siri & Brozek ($p < 0.001$), and significantly lower than the method of determining the percentage of body fat according to Jackson Pollock ($p = 0.005$). The research showed that in the observed sample of respondents, when it comes to one respondent, a group of respondents, respondents within one sport or an uneven sample of non-athletes, if it is not possible to use some of the more sophisticated BIA methods, a satisfactory method could be the skinfold measurement method.

Keywords: *skinfold measurement method, bioelectrical impedance, body fat, kayak canoe slalom*

COMPARISON OF METHODS FOR DETERMINING PERCENTAGE OF BODY FAT ON A SAMPLE OF KAYAKERS AND CANOEISTS – IN SLALOM

INTRODUCTION

Kayak canoe slalom is an Olympic sport regulated by the rules of the International Canoe Federation (ICF). Competitors race on a course a maximum of 400m long with natural or artificial obstacles to the water flow (ICF, 2019). An experienced competitor usually needs 75-95 seconds to master the course, the fastest overall time. (Macdermid, et al., 2019).

Slalom racers use a combination of technically demanding movement structures associated with short accelerations and high-intensity rowing, which requires resynthesis of energy through anaerobic metabolism. (Messias et al., 2014).

According to Zamparo et al. (2006) aerobic energy source accounts for about 50% (aerobic - 45.2%; anaerobic alactic - 24.9; anaerobic lactic - 29.0%) of the total metabolic energy turnover in a slalom race. The importance of aerobic metabolism in slalom skiers has been shown in other studies (Ferrari et al., 2017; Manchado-Gobatto et al., 2014; Messias et al. 2015). Bielik et al. (2019) conclude that slalom skiers may benefit from the oxidative system during rest in or interval training. The role of fat in the oxidative system as an energy source is significant (Gollnick, 1985; Achten, & Jeukendrup, 2004), and as slalom training is on average 1.5-2 hours long, the importance of mass as an energy source is not negligible.

Excess of fat percentage negatively affects the performance of slalom racers. The increased weight of the rowers causes boats to sink deeper into water, increasing a contact area, ie. total frictional resistance and wave resistance, thus increasing the resistance that the rower must overcome in order to push the boat forward. (Lundström, Borgen, & McKenzie, 2019).

Data from anthropometric measurements in recent decades, at competitors in kayaking and canoeing, show a lower percentage of body fat and increased musculature of the upper body and arms, which is associated with performance and more successful rowing. (Lundström, Borgen, & McKenzie, 2019; Hagner-Derengowska et al., 2014). Previous studies have shown that there is no significant difference between canoeists and kayakers in the percentage

of body fat, and the authors explain that this is caused by both groups having identical track sections and training aimed at improving strength and speed, resulting in increased muscle mass. (Kameyama et al., 1999; Hamano et al., 2015).

Determination of body structure, and especially the percentage of body fat, is done in order to control the training of athletes to assess health status, possible risks, as well as control health status during diets (Malina, 2007; Ackland et al., 2012), and Wells & Fewtrell (2006) point out that the measurement of body structure in vivo is an imperfect process and that it is subject to various limitations, but that it has significant clinical value in pediatric practice.

The validity of BIA bioelectric impedance method has been investigated in numerous studies. The validity of this method in relation to hydrodensiometry, skinfold measurement method, ADP (plethysmography of whole body volume) was confirmed and a large correlation was found between the total conductivity of the human body and the fat-free component (Keller & Katch, 1985; , Graves, & Mahar, 1988; Macias, Alemán-Mateo, Esparza-Romero, & Valencia, 2007).

Wang, Zhang et al. (2013) comparing four different systems on the principle of bioelectric impedance with DEXA and MRI methods obtained a high level of correlation r=0.71-0.89 to estimate the percentage of body fat. They conclude that the devices are accurate in assessing body composition, especially skeletal muscle mass and fat-free component. A high degree of correlation of the BIA method with the DEXA method was also established by Fornetti, Pivarnik, Foley & Fiechtner (1999), as well as Company & Ball (2010).

Wells & Fewtrell (2006) believe that it is less accurate than DEXA, that there are limitations to estimating whole body composition using the skinfold measurement method and BIA, and state that applying a combination of both methods can reduce the probability of error, which should be borne in mind because the data obtained by determining the structure of the body provide insight into the current state and represent the starting point for planning and programming training and exercise to achieve or maintain optimal and desirable

relations of different tissue types.Incorrect assessment of the thickness of subcutaneous body fat, and thus the total fat content using the skinfold measurement method, with the main problems being the impossibility of palpation of fat-muscle demarcation and the impossibility of reliable measurement in obese people, has been documented in previous studies (Brozek, & Kinsey, 1960; Himes, Roche, & Siervogel, 1979). Disadvantages of this method include compression of subcutaneous body fat during measurement and the possibility of measurement only at certain points (Lohman, 1981; Burkinshaw, Jones, & Krupowics, 1973). The skinfold measurement method is simple, fast and informative, but there are limitations in very obese people as well as in significant deviation of regional tissue distribution in relation to average people, therefore standardized equations have been developed which based on skin folds, according to gender, age and other population nature (physical activity, specific disease, race) calculate the percentage of body fat: special equations for adults (Jackson & Pollock, 1982), special equations for men (Jackson & Pollock, 1978), for the female population (Jackson, Pollock & Ward 1980), special formulas for male athletes (Sinning, Dolney, & Little, 1985; Forsyth & Sinning, 1973; Sinning, 1974; Pollock, Gettman, Jackson, Ayres, Ward, & Linnerud, 1977), and special formulas for female athletes (Sinning, 1978; Meleski, Shoup, & Raspberry, 1982; Sinning & Wilson, 1984 and Mayhew, Clark, McKeown, & Montaldi, 1985). Since the equations developed for one sample cannot always be applied with great reliability to another sample, special formulas have been developed for certain sports: for long-distance runners (Pollock, Gettman, Jackson, Ayres, Ward, & Linnerud, 1977), wrestlers (Sinning, 1974), gymnasts (Sinning, 1978), swimmers (Meleski, Shoup, & Malina, 1982), etc.This research was conducted in order to determine the validity of the method of calculating the percentage of body fat based on the skinfold measurement method in relation to the bioelectrical impedance method in slalom kayakers and slalom canoeists, to select and apply the appropriate method, its accuracy and precision in their training process.

RESEARCH METHODS

The sample of respondents consisted of athletes - 49 male kayakers and canoeists, aged 19.9 ± 1.7 years, participants in the European Kayak Canoe Slalom Championship in the category of juniors and younger seniors. The respondents were representatives of Germany, Poland, Slovakia, Slovenia and Croatia and were of normal health status and voluntarily joined the survey. Since the respondents are top kayakers and canoeists who secured a place in the national selections through election races, and that these teams represent the most competitive teams, this is a sample that has been included in the training process for many years.

The research was conducted in the morning three days before the start of the championship in the cabinet for anthropomotorics at the Faculty of Physical Education and Sports in Banja Luka. The instruments were of standard workmanship and calibrated. Due to the way the data were taken, the respondents were dressed in underwear and without socks, did not consume alcohol for at least 72 hours, food and fluids for at least 4 hours, did not exercise for at least 12 hours before the measurement, nor were they diuretic users.

A Martin anthropometer was used to collect data on the height of the respondents, according to the protocol and methods of measuring anthropometric dimensions according to IBP. Anthropometric estimation of body density and fat content in the structure of body composition and upper extremities was determined using bioelectrical impedance method and body composition analyzer of brand Tanita model BC 418-MA III (Tanita, Tokyo, Japan) by passing a low current of 800 μamp through body of a respondent. The measurement was performed in the protocol provided conditions (room temperature 22 - 24°C in a quiet environment) according to the protocol of preparation for the measurement. Since the percentage of body fat according to Siri, Brozek and Jackson and Pollock is determined by equations, before determining the percentage of body fat it was necessary to determine the values of skin folds (triceps, pectoral, midaxillary, abdominal, suprailiac, suprascapular and thigh) and body density on the basis of equations

with skin folds. The skinfold measurement method was done using a Harpenden caliper with a measuring range from 0 to 40 mm according to the IBP standard.

The bioelectrical impedance method and the skinfold measurement method were used to determine the percentage of body fat of the respondents. The specificity of the skinfold measurement method is that there are different formulas of different authors for estimating the percentage of body fat, which are all based on the same formula for calculating body density and for the purposes of this research the following formulas were used:

a) Fat (%) = (4.95/BD-4.5)*100 men (Siri, 1957; according to: Sudarov & Fratic 2010)
b) Fat (%) = (4.57/BD-4.142)*100 (Brozek et al.1963)
c) Fat (%) = 0.29288 *Σ4 – 0.0005 * (Σ4)2+ 0.15845 x A – 5.76377, (Jason & Pollock, 1985)

For the Siri and Brozek formulas, it was necessary to determine the value of seven skin folds: triceps, pectoral, midaxillary, abdominal, suprailiac, suprascapular and patellar skin fold, while for the Jason and Pollock formula it was necessary to determine the values of four skin folds (mm): abdominal, triceps, patellar, and suprailial skin folds.

From the envlosed it can be seen that all three formulas when calculating the percentage of fat use A (age of the subjects) and BD - body density calculated using the equation for men from 18 to 29 years according Jason i Pollock (1978):

BD = 1.12 - 0.00043499*Σ7 + 0.00000055*(Σ7)2 - 0.00028826*A.

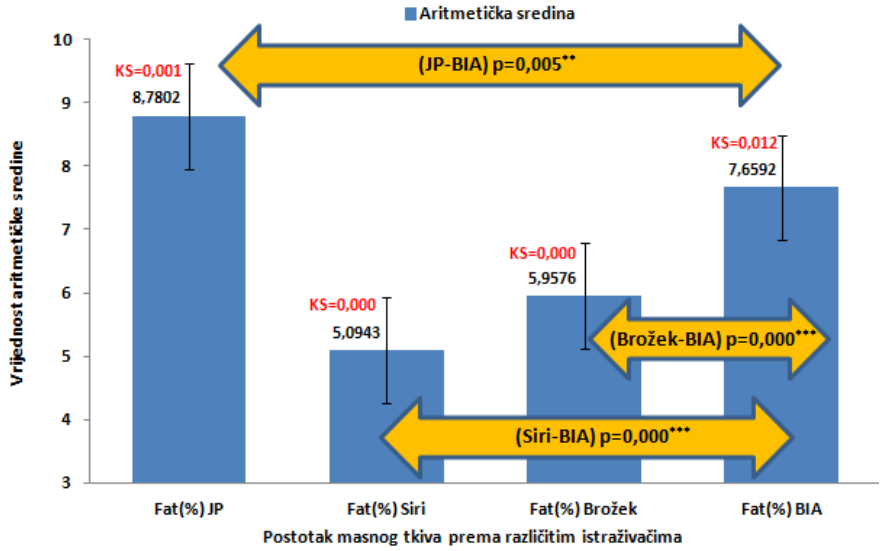
Statistical analysis

Descriptive statistics methods were used for statistical data processing, Kolmogorov-Smirnov test for determining normality of distribution, correlation between skinfold measurement method and BIA method were determined by Spearman correlation coefficient, and Wilcoxon test was used to compare body fat percentage values obtained by anthropometric and BIA

method. Values in which p <0.05 were taken as statistically significant. All experimental data were analyzed using SPSS version 20.0 statistical software (SPSS Inc, IBM-Company, Chicago, IL, USA).

RESULTS

Chart 1. *Percentage of body fat according to different methods*



Legend: Y axis arithmetic mean ± standard deviation; KS - Kologorov-Smirnov test (statistical significance); p - Statistical significance of Wilcoxon test for paired samples; Fat (%) JP - percentage of body fat according to Jackson and Pollock; Fat (%) Siri - percentage of body fat according to Siri; Fat (%) Brozek - percentage of body fat according to Brozek; Fat (%) BIA- percentage of body fat according to BIA

The difference between the arithmetic means measured on the basis of the methods according to Siri and Brozek (5.09; 5.96) is significantly smaller than the results obtained by the BIA bioelectrical impedance technique (7.66), while the highest values of the percentage of body fat were shown by the Jackson Pollock method (8.78). The largest error of the arithmetic mean is shown by the BIA method (0.63) followed by the Jackson Pollock method (0.57), while the standard errors of the arithmetic mean of the methods according to Siri and Brozek have lower values (0.50) and (0.46), respectively. The normality of the distribution was tested (Chart 1) by the Kolmogorov-Smirnov test of normality, which showed that none of the observed methods had a

normal distribution, which was expected considering the selected group of kayakers and canoeists.

Verification of the degree of correlation of methods for determining the percentage of body fat was performed by Spearman correlation analysis. The obtained result indicates that the coefficient has a statistically significant value at the level of significance p=0.01, ie. 99%. The correlation coefficient of the BIA method (MT (%) BIA) with the methods according to Siri and Brozek (MT (%) Siri and MT (%) Brozek) is 0.667, which is a very high correlation, while with the method according to Jackson Pollock (MT (%)) JP) is slightly lower 0.636. The values obtained by the Siri and Brozek equations are completely correlated, while the Spearman coefficient of both methods is in relation to the method of the Jackson Pollock equation r = 0.975.

Thus, after the analysis of the correlation coefficient of the percentage of body fat determined by applying three different methods, it can be concluded that a high statistical correlation of variables was observed.

The Wilcoxon test showed the existence of significant differences in the obtained values by anthropometric methods in relation to the bioelectrical impedance of BIA. Comparing the medians MT(%) JP and MT(%) BIA (7.50 and 6.80, respectively) showed that the BIA method shows statistically significantly (p = 0.005) lower values of the percentage of body fat compared to the Jackson Pollock method. On the other hand, comparing the median MT(%) Siri (4.20) and MT(%) Brozek (5.13) with MT(%) BIA (6.80) showed that there was a statistically significant difference (p <0.001). The BIA method shows statistically significantly higher values of the percentage of body fat compared to the two methods based on seven skin folds. (Chart 1).

DISCUSSION

In this study, four methods for estimating the percentage of body fat in body structure were compared: three based on the skinfold measurement method and the method of bioelectrical impedance. Their common features are that they are non-invasive, simple, fast and relatively cheap.

According to the correlation analysis, a high correlation of the methods was observed: anthropometric methods according to Siri and Brozek are completely correlated (1.000), both methods with the Jackson Pollock method have a slightly lower coefficient ρ=0.975, while all three methods have a high level of correlation with the BIA method, which indicates that it is possible to predict one variable based on another. The obtained results are in line with previous research (Jackson, Pollock, Graves & Mahar 1988; Bascevan, Vucetić, & Rodic, 2011; Utter et al. 2001; Ostojic, 2006).

The Wilcoxon test showed significant differences in the values obtained by anthropometric methods compared to the BIA method. The measurement methods according to Siri and Brozek have statistically significantly lower values of the percentage of body fat, while the method according to Jackson Pollock showed statistically significantly higher values compared to BIA. Similar results have been found in other studies (Knechtle, B., Knechtle, P., & Rosemann, 2011; Michailidis, Methenitis, & Michailidis, 2013). The basic question that arises is which of these methods is more precise and valid?

Numerous studies have confirmed the reliability of bioelectrical impedance with respect to hydrodensiometry, Keller & Katch (1985); Lukaski et al. (1985); Jackson, Pollock, Graves, & Mahar, (1988). The precision and validity of bioelectrical impedance relative to ADP whole-body volume platysmography have been established by Macias, Alemán-Mateo, Esparza-Romero, & Valencia (2007). The accuracy of the BIA system in relation to DEXA has been established in many studies (Wang, Zhang et al. 2013; Fornetti, Pivarnik, Foley & Fiechtner 1999; Company & Ball (2010)). When it comes to

anthropometric methods based on equations based on which the percentage of body fat is calculated over skin folds, numerous studies also show consistency and that they correlate with the DEXA method (Lintsi, Kaarma & Kull, 2004; Bowden et al. 2005). It has been shown here that skinfold measurement methods have a significantly higher correlation coefficient with the DEXA method than the BIA method. This can be partly explained by the development of a number of equations for calculating the percentage of body fat across skin folds, which are specialized for a specific population by sex (Jackson & Pollock, 1982), especially for men (Jackson & Pollock, 1978) and especially for women (Jackson & Pollock, 1980) or by activity (Sinning, Dolney, & Little 1985; Forsyth & Sinning, 1973; Sinning, 1974; Pollock, et al. 1977). On the other hand, some studies have indicated the inaccuracy of these equations compared to the DEXA and ADP method (Silva, Fields, Quitério, & Sardinha, 2009) where it was concluded that these anthropometric methods are not valid for estimating and monitoring changes in fat and fat-free percentage with highly trained judokas before and after the competition. Brodie, Moscrip, & Hutcheon (1998) extensive research of a large number of papers dealing with various body composition assessment systems including chemical, electrical, physical and anthropometric, concludes that sophisticated body structure assessment devices such as computerized tomography scanners are available mainly to large institutes with high budgets. However, they find that the clinical experience of many nutritionists has shown that it is possible to very successfully apply low-budget methods which are fast and non-invasive.

In this study, although the methods according to Siri and Brozek are highly correlated with the method according to Jackson Pollock, on the other hand, statistically significantly higher and lower values compared to the BIA were measured. This research showed that in the case of top slalom kayakers and slalom canoeists who participated in the research, not all equations show the same value. Of course, it is necessary to look at possible factors that may have contributed to such results. The value of the percentage of body fat for the results obtained by the

skinfold measurement method according to Siri, Brozek and Jackson and Polok could be influenced by the method of measurement in which there was a possibility of error even though performed by the same measurer, and uneven distribution of tissue in proportion to the specifics of the sport, while the results obtained by the BIA method could be affected by insufficient preparation of athletes to perform measurements (measurement was performed three days before the competition and each athlete has special preparations for the competition that should not be affected - supplementation, nutrition and hydration regime, training schedule, etc.). Also, it should be taken into account that this was a transversal type study and the specificity of the sample on which the study was conducted, because they were athletes who underwent training for many years, and to get more valid results of such studies it would be desirable such measurements spend significantly more often on the same population of athletes. The research showed that in this sample of respondents, if it is not possible to use one of the more sophisticated methods of the BIA method type, the satisfactory method could be any of the three observed methods of measuring skin folds. It is important to always use the same method. Of course, this claim cannot be generalized.

CONCLUSION

Today, there are specific equations for calculating the percentage of fat by anthropometric methods for individual sports. Developing a special equation for kayakers and canoeists would help determine the percentage of fat more precisely with this cheapest and most mobile method.

Also, it has been shown that in sports training of kayakers and canoeists, depending on financial possibilities, if one wants to constantly monitor the percentage of body fat of athletes, there is a choice between two methods of determining the percentage of body fat - using Body composition analyser or measuring skin folds with a caliper and then determining the percentage of body fat via a formula according to Jackson Pollock and Siri and Brozek. From a practical point of view, it is clear that due to the practicality and simplicity of measurement and the speed of data acquisition, the method of bioelectrical impedance is preferred. However, when you look at the economic situation in sports, and that the price of a device for measuring bioelectrical impedance, for our circumstances, is not so low, measuring body structure by methods through skin folds is certainly valid enough and more affordable. If we are talking about smaller groups of athletes and if the measurements are performed by the same measurer with the same caliper, the possibility of error is further reduced.

In order to be able to say with certainty which of the measured methods is the most valid for assessing body composition in the kayak canoe sport, it would be necessary to include a much larger sample and compare the processed methods with the most accurate methods such as DEXA, ADP or hydrodensiometry.

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COMPARISON OF METHODS FOR DETERMINING PERCENTAGE OF BODY FAT ON A SAMPLE OF KAYAKERS AND CANOEISTS – IN SLALOM

SAŽETAK

Određivanje tjelesne strukture u fizičkoj kulturi, sportu, ali i u sportskoj rekreaciji jedan je od načina za provjeru efikasnosti određenih trenažnih programa i njihovog uticaja na postotak potkožnog masnog tkiva i nemasne komponente. Ovo istraživanje provedeno je na uzorku od 49 kajakaša i kanuista slalomaša (starosti 19,9 ±1,7 godina), sa ciljem upoređivanja validnosti metoda procjene postotka masnog tkiva koje se baziraju na metodi mjerenja kožnih nabora u odnosu na metodu bioelektrične impendance radi primjene u dijagnostici trenažnog procesa kod kajakaša i kanuista slalomaša. Postotak masnog tkiva utvrđen je metodama utvrđivanja postotka masnog tkiva prema Siriju (1961), Brožeku i sar. (1963), Jackson, i Pollock, (1985) i metodom bioelektrične impedanse BIA. Nakon provedenih statističkih procedura, korelacionom analizom utvrđena je visoka povezanost metoda: antropometrijskih metoda po Siriju i Brožeku, obje metode sa metodom po Džekson Poloku, dok sve tri metode imaju visok nivo korelacije sa metodom BIA, dok je Wilcoxon test pokazao da metoda bioelektrične impedance ima statistički značajno veće vrijednosti od metoda utvrđivanja postotka masnog tkiva prema Siriju i Brožeku ($p<0.001$), a značajno manje u odnosu na metodu utvrđivanja postotka masnog tkiva prema Džekson Poloku ($p=0.005$). Istraživanje je pokazalo da bi na posmatranom uzorku ispitanika, kada je u pitanju jedan ispitanik, grupa ispitanika, ispitanici u okviru jednog sporta ili neujednačeni uzorak nesportista, ukoliko nema mogućnosti za korištenje neke od sofisticiranijih metoda tipa BIA, zadovoljavajuća metoda mogla biti metoda mjerenja kožnih nabora.

Ključne riječi: *metod kožnih nabora, bioelektrična impedanca, kajak kanu slalom*

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EFFECT OF AEROBIC EXERCISE ON BODY COMPOSITION OF OVERWEIGHT FEMALE; INSPIRING UNIVERSITY STUDENTS TO PRACTICE AND RECEIVE MORE ADVANTAGEOUS WAY OF LIFE

EFEKAT AEROBNIH VJEŽBI TJELESNU GRAĐU ŽENA SA PREKOMJERNOM TEŽINOM; NADAHNJUJUĆI STUDENTE DA VJEŽBAJU I IMAJU KVALITETNIJI NAČIN ŽIVOTA

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ABSTRACT

The purpose of this study aimed to look at assessing the effects of aerobic exercise on body composition of overweight female aging 22-27 years.A sample of n=30 (thirty) overweight female aging 22-27 years in District Tonsa (Punjab), Pakistan were included as subject. A four (04) week exercise protocol was prepared and used among females of the experimental group.

The experimental group was subjected to measure the anthropometric as well as 3- site skin fold measurements. The data regarding pre and post-test of both groups-control and experimental were carefully recorded and entered into the computer for analyses. For this purpose, both descriptive (mean and standard deviation) and inferential statistics (Independent Samples t-Test and Paired Samples t-Test) were used for analyzing the data. The analyzed data established that the mean score of (EG) in pre and post-test were found as 28.66 and 23.5. The t-value of the table is 5.022 and P-value is 0.001 which is lower than the significant level (P<0.05).

Therefore, it is concluded that the difference between Pre and Post-test of Control Group has shown the significant effects of aerobic exercises on body fat percentage of overweight females. According to the analyzed data the mean value of Post-tests regarding body fat percentage of Control Group were 28.89 and Experimental Group was 23.5. The P-value 0.002 and t-value -987 in the table depict the significant statistical difference between the two means of Control and Experimental Group in Body Mass Index (P<0.05).The results of the study indicated that the four weeks' aerobic exercise protocol has a significant effect on overweight females in the perspective of decreasing their body fat percentage. Based on the findings, the researcher recommended that more and more involved in physical activity and exercise among female folk may be ensured.

Key words:

Effect, aerobic exercise, body composition, overweight, university students, advantageous life.

INTRODUCTION

Leading a happy and a successful life is the innate quest of all human beings. Good physique and sound health are the prerequisites to satisfy this human desire. One may take part in exercise to achieve optimal physical fitness. It is a matter of common observation that majority of us particularly among female folk leads sedentary life and findings of the research states that in sedentary lifestyle the human health is obviously prone to various unfavorable situations like obesity, weight gain, hypertension and other chronic diseases (Tudor-Locke, Craig, Thyfault, & Spence 2013). In this regard, participation in some kind of daily exercise occupies its own remarkable role in the maintenance and promotion of good health (Stathi, Fox, Withall, Bentley, & Thompson 2014). Research reveals that people who possesses optimal body composition seems to be healthier and feel better about themselves. It is very much important to know the right body composition and then focus towards the achievement and maintenance of it (Campos,2004).

Even though, in our society women are not paying due consideration to the idea of exercise. For some individuals a prompter objective is to look fit and solid. Subsequently, numerous individuals don't get into the endeavors of fitness and solid body. Research suggested that effective management of body composition needs the harmonization of numerous characteristics including proper diet, stress management and more significantly adequate amount of exercise (Slentz, Aiken, Houmard, Bales, Johnson, Tanner, & Kraus, 2005). According to Kang et al. (2002) daily exercise results in the successful management of body composition.

The purpose of controlling body weight is actually a matter of adjusting body fat. In this regard, research reveals that achievement of healthy body composition not solely conform rigid standards of human wellbeing rather exercise is the key to achieve the goal of wellness in life style (

Faigenbaum, Chu, Paterno, & Myer 2013). Several studies confirm that excess amount of body fat cause for various health problems like obesity, cardiovascular diseases (CVD) hypertension and diabetes (Bastien,Poirier, Lemieux, &Després 2014; Lavie et al., 2016). Viewing upon this notion, result of the research revealed that women who are obese are more likely to suffer from menstrual abnormalities, and complications during pregnancy (Mandviwala, Khalid, &Deswal 2016) which match the findings of the study, conducted by Paladini(Paladini, 2009) found that obese women suffer from respiratory problems and joint diseases and more significantly complications during pregnancy. Study described that reduction of 5-10 % weight loss helped in the control of various heart problems including stroke, diabetes and other weight related disorders (Look AHEAD Research Group, 2016).

Participating in aerobic exercise play a vital role in controlling the weight ranged contributes to promoting mental and physical health as well. Health conscious people should take active part in physical activities to diminish anxiety, stress, and depression. They will sleep well, and feel much better and relaxed throughout the day. Lowry et al. (2000) recommended that 30 to 40 minutes' vigorous exercises several times per week are probably right for weight management. Regular, aerobic exercise is necessary for the survival of evolution. It is

possible to go through life with less physical activity than those in the past decades. Promotes the welfare of the living modern comfort and low energy; however, humans are not genetically adapted to the sedentary lifestyle. Physical activities initiate various adjustments inside skeletal muscles and the cardiorespiratory framework, all of which giving positive results to the counteractive action and treatment of numerous metabolic issue. Absence of practice ought to rather be seen as "anomalous" and related with various wellbeing dangers.

Keeping in view the brief discussion on the importance and vitality of aerobic exercise with reference to the body composition particularly among women, the researcher conducted a study entitled effects of aerobic exercise on body composition of overweight female aging 22-27 years in District Tonsa (Punjab), Pakistan.

The goal of the research is to evaluate the effect of aerobic exercise on body mass index and body fat percentageamong overweight females aging 22-27 years.

METHOD AND MATERIALS

The research methodology used in this study is described below.

Research Design

Experimental research provides a systematic and logical method for answering the questions or testing the hypotheses. The experimental method provides a reliable way of studying the relationship between two variables under carefully controlled conditions (Kothari, 2004). Experiments can be conducted either in the laboratory or in the field. Field experiment is more suitable when the researcher wants to minimize the possibility that people will change their typical behaviour(Frankfort-Nachmias, &Nachmias 2007). Therefore, the researcher adopted field experiment.

Study Participants

Those overweight female who had never exercised were included in the study. For this purpose, thirty (30) volunteer agreed to participate in the study. The health risks of the subjects were verbally

inquired because the health conditions of the carefully chosen subjects were critical for the study. Therefore, the researcher put forth considerable attention to some of the major health issues like diabetes, hypertension, asthmatic problems which can make complications during the intervention period.

On the basis of Body Mass Index (BMI), a list of thirty subjects in rank order was prepared. Two identical groups were randomly framed on the basis of even and odd numbers in such a way to associate both the groups according to their BMI. One group was labeled as the Experimental Group (EG) n=15 and the second group was labeled as the Control Group (CG n=15).

Research Instrument

For registering the measurements and personal data of the subjects, the researcher designed a chart in order to measure the anthropometric variables, including age, height and weight. For the purpose, the subjects were asked to mention their age. Measures of Height and weight were recorded with the help of Stadiometer. For three site skin fold measurements (Triceps, Suprailic and Thigh Muscles) Skin Fold Caliper was used to determine the body fat percentage of the subject.

Pre-test

Keeping in view the related studies pre-test was designed which focused age, height, weight and three Sites Skin Fold measurements. All the qualifying forty subjects underwent pre-test and their age, height, weight and three Sites Skin Folds were measured and recorded on the chart. Body Mass Index (BMI) and Body Composition were computed by standardized formula devised by (AdolpheQuetelet in the 1900's) for calculating the Body mass index of the individual subject weight (Kg) was divided by their height (m) 2. For 3-site skin fold measurements Triceps, Suparilic, and Thigh muscles were measured with the help of Skin Fold Caliper. Participant were required to remove shoes and heavy outfit before the measurements of height and weight. Measurements of each participant were taken by the same evaluator/investigator. The data were recorded and tabulated very carefully for analysis. On the basis of variables body mass Index and body fat percentage of every subject was determined.

Research Protocol

A four (04) week exercise protocol which could meet the set objectives of the study was designed and used among females of experimental group. The experiment of aerobic exercises spread over duration of four weeks and applied only on the experimental group (n=15). The control group (n=15) was given no treatment. Aerobic exercises were selected and four weeks' exercises protocol was formulated to treat the experimental group. A total of four weeks' program was formulated having four training day and three resting days on alternate basis in each week. The recommended detailed program is given in the exercise protocol.

Post-test

The experimental group was subjected to measure the anthropometric as well as 3-site skin fold measurements after the treatment of four weeks' exercise protocol.

Statistical Analysis

The data regarding pre-test of all the subjects were coded and entered into computer carefully. The Body Mass index and body fat percentage of each subject was computed. The data regarding post-test of both groups-control and experimental were carefully recorded and entered into the computer for analyses. For this purpose, both descriptive (mean and standard deviation) and inferential statistics (Independent Samples t-Test and Paired Samples t-Test) were used for analyzing the data.

RESULTS

Descriptive analysis:

Table 1. *Pre-Test-Anthropometric and 3- site skin fold Measurements (n=30)*

Parameters	(CG) Mean ± SD	(EG) Mean ± SD	p-value
Age	23.55 ± .992	32.9 ± 1.64	0.008
Height (Inches)	63.85 ± 1.65	64.9 ± 2.44	0.645
Weight (kg)	75.2 ± 4.98	74.08 ± 6.47	0.509
Body Mass Index (kg/m)2	29.78 ± 2.48	29.88 ± 2.37	0.511
Body Fate Percentage	28.58 ± 2.78	29.13 ± 3.96	0.513

Significant at 0.05 level

Data regarding anthropometric characteristics and 3-site skin fold Measurements of Thirty (30) participants are shown in the above table. According to the table 1, the mean age, height and weight of the control group were 23.55 ± .992 years, 63.85 ± 1.65 and 75.2 ± 4.98 respectively. Whereas, the mean age, height and weight of the experimental group were 32.9 ± 1.64, 64.9 ± 2.44 and 74.08 ± 6.47. Based upon the above measurements, the mean values of the body mass index of control and experimental group were calculated (Kg/m^2) 29.78 ± 2.48 and 29.88 ± 2.37. Likewise, 3-site skin fold measurements of both the groups were recorded by Skin Fold Caliper and mean values were obtained as 28.58 ± 2.78 and 29.13 ± 3.96.

To find out the difference in pre-test of control group and experimental group in terms of body mass index and body fat percentage, t-test was applied and the results has showed that there was no statistical significant difference between the two groups(P>0.05).

Table 2. *Pre and Post-test results of Control Group (CG) and Experimental Group (EG) in Body Mass Index*

Variable	**Control Group (CG)**	**Mean**	**SD**	**t-value**	**P-Value**
Body Mass Index	Pre-test	38.78	3.26	0.856	0.392
	Post-test	38.86	3.21		
Variable	**Experimental Group (EG)**	**Mean**	**SD**	**t-value**	**P-Value**
Body Mass Index	Pre-test	29.74	3.26	21.56	0.003
	Post-test	26.64	3.62		

Significant at 0.05 level

The above table 2 revealed the mean difference in Pre and Post-test results of Control Group (CG) in term of Body Mass Index. Accordingly, the data shown that the mean score of control group in pre and post-test were found as 38.78 and 38.86. The t-value of the table is 0.856 and P-value is 0.392 which is higher than the significant

level (P>0.05). Therefore, it is concluded that the difference between Pre and Post-test of Control Group has shown no significant increase in body mass index. The table is also showing the mean difference in Pre and Post-test results of Experimental Group (EG) in term of Body Mass Index. The mean score of (EG) in pre and post-test for BMI were found as 29.74 and 26.64. The t-value of the table is 21.56 and P-value is 0.003 which is lower than the significant level (P<0.05). Therefore, it is concluded that the difference between Pre and Post-test of Control Group has shown significant decrease in body mass index.

Table 3. *Mean, Standard Deviation and't' ratio of Post-test results of Control and Experimental Group in Body Mass Index*

Group	Test	Mean	SD	t-value	P-value
Control	Post	38.86	3.21	-21.56	0.003
Experimental	Post	26.64	3.62		

Significant at 0.05 level

The above table no 3 shows Mean, Standard Deviation and 't' ratio of Post-test results of Control and Experimental Group in Body Mass Index. According to the analyzed data the mean value of Post-tests regarding BMI of Control Group was 38.86 and Experimental Group was 26.64. The P-value 0.003 and t-value -21.56 in the table depict the significant statistical difference between the two means of Control and Experimental Group in Body Mass Index (P<0.05). Henceforth, it is concluded the four weeks' aerobic exercise protocol has significant effect on overweight females in perspective of decreasing in their body mass index.

Table 4. *Pre and Post-test results of Control Group (CG) in Body Fat Percentage*

Variable	**Control Group (CG)**	**Mean**	**SD**	**t-value**	**P-Value**
Body Fat Percentage	Pre-test	28.18	4.12	-0.988	0.346
	Post-test	28.89	289		
Variable	**Experimental Group (EG)**	**Mean**	**SD**	**t-value**	**P-Value**
Body Fate Percentage	Pre-test	28.66	3.98	5.022	0.001
	Post-test	23.5	2.6		

Significant at 0.05 level

The table 4 has reveals the mean difference in Pre and Post-test results of Control Group (CG) in term of body fat percentage. The mean score of control group in pre and post-test were found as 28.18 and 28.89. The t-value of the table is -0.988 and P-value is 0.346 which is higher than the significant level (P>0.05). Therefore, it is concluded that the difference between Pre and Post-test of Control Group has shown no significant increase in body mass index. From the analysis it can be said that sedentary life style among overweight females produced no significant difference during the duration of experimentation period.

The table is also showing the mean difference in Pre and Post-test results of Experimental Group (EG) in term of body fat percentage. The analyzed data have established that the mean score of (EG) in pre and post-test were found as 28.66 and 23.5. The t-value of the table is 5.022 and P-value is 0.001 which is lower than the significant level (P<0.05). Therefore, it is concluded that the difference between Pre and Post-test of Control Group has shown significant effects of aerobic exercises on body fat percentage of overweight females.

Table 5. *Mean, Standard Deviation and't' ratio of Post-test results of Control and Experimental Group in Body Fat Percentage*

Group	Test	Mean	SD	t-value	P-value
Control	Post	28.89	2.89	-21.87	0.002
Experimental	Post	23.5	2.6		

Significant at 0.05 level

The above table 5 is showing Mean, Standard Deviation and 't' ratio of Post-test results of Control and Experimental Group in body fat percentage. According to the analyzed data the mean value of Post-tests regarding body fat percentage of Control Group was 28.89 and Experimental Group was 23.5. The P-value 0.002 and t-value -987 in the table depict the significant statistical difference between the two means of Control and Experimental Group in Body Mass Index ($P<0.05$). Hence, it is concluded that four weeks' aerobic exercise protocol has significant effect on overweight females in perspective of decreasing in their body fat percentage.

DISCUSSION

In response to first hypothesis, the data revealed that aerobic exercise has positive impact on the body mass index of overweight females aging 22-27 years. It is additionally proposed by the researcher that a human body needs a five-day practice in seven days, independent of what age group he/she is placed in. The same study has found that a normal exercise keeps our body fit as well as it helps in keeping up our body in a normal weight. In another study, indicated that that exercise expands the blood dissemination of the body and sets the individuals us up for the diligent work throughout the day (Cousins, 2000). Research suggested that short term exercise can avoid incessant ailments and other medical issues identified with lungs and heart (Mostert& Kesselring 2002). General practices help to fortify the heart and the bulk can increment and the weight can be controlled through daily aerobic exercise (Agarwal, 2012).

The second hypotheses revealed that the aerobic exercise has positive effects upon body fat control of overweight females aging, which have been accepted by the analyzed data. These findings are supported by the findings of Halle et al.(1999) who found that taking part in any exercise and use of balance diet are the true benefactors which helps in losing body fat than depending on the calorie restriction. Exercise can avert or even inverse the effects of certain diseases while, another study has concluded that exercise let down blood pressure and the level of cholesterol, which in turn helps in the prevention of heart attacks (Swain & Franklin 2006; Ciolac et al., 2008).

In summary, regular physical activity appears to confer a health benefit to the people. However, further research is necessary to examine its role in the prevention of different diseases. In particular, large RCTs evaluating the effectiveness of an exercise intervention are required to fully elucidate the importance of regular physical activity for the health status of patients with cancer.

CONCLUSION

Obesity has become a worrying health and social issue. This present study examined this issue to assess the effects of aerobic exercise on body composition of overweight female aging 22-27 years in the vicinity of District Tonsa, Punjab. Accessing to the findings of the study there existed significant effects of four weeks' aerobic exercises with special reference to the body composition among overweight female aging 22-27 years on the targeted population. Likewise, the study has concluded that the aerobic exercise protocol also helps in decrease the ratio of body fat percentage and body mass index but increase lean body mass.

It has also been concluded that there is a positive relationship between aerobic exercises and overweight women in order to reduce the value of fat in the body. It is consequently to say that aerobic exercise at some level and for a specific duration would be essential to preserve and maintain the complete fitness and anthropometric benefits of exercise among overweight women. A downward trend towards the ignorance of

any physical exertion and take a high calorie diet will lead to increases in the value of fat in the body. This research has shown the exercises protocol for those women who are cognizant about their health; they will easily execute the recommended protocol at their home. This study supports the worth of aerobic exercise in the treatment of obese or overweight women also lighting the importance of aerobic on daily basis.

LIMITATION AND FUTURE SUGGESTIONS

The present study was carried out among the university level students, the researcher is ambitious to inclusion of larger and diverse population would help in adding to the credibility of future research in this area. This study was conducted to assess the effects of aerobic exercise upon females. Another study be conducted among males. This study was focused to assess the effects of aerobic exercise among age group of 22-27. Similar study may also be carried out on male of different age groups for the improvement in their fitness level of male for healthy society.

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CONFLICT OF INTEREST

No conflict of interest has been found in the study.

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EFFECT OF AEROBIC EXERCISE ON BODY COMPOSITION OF OVERWEIGHT FEMALE; INSPIRING UNIVERSITY STUDENTS TO PRACTICE AND RECEIVE MORE ADVANTAGEOUS WAY OF LIFE

SAŽETAK

Istraživanje je provedeno sa ciljem procjenjivanja efekata programa aerobnih vježbi na tjelesni sastav žena sa prekomjernom tjelesnom težinom u dobi od 22 do 27 godina. Uzorak od 30 žena sa prekomjernom težinom u dobi od 22 do 27 godina iz okruga Tonsa (Pandžab), Pakistan bio je uključen u istraživanje. Program vježbanja od četiri sedmice pripremljen je i proveden sa ispitanicama eksperimentalne grupe. Eksperimentalna grupa je podvrgnuta mjerenju antropometrijskih, kao i mjerenja kožnih nabora (3 nabora). Podaci izmjereni prije i poslije programa (kod kontrolne i eksperimentalne grupe) su pažljivo zabilježeni kao baza podataka. Za dobijanje valjanih zaključaka korištene su deskriptivna (srednja i standardna devijacija) i inferencijalna statistika (nezavisni uzorak t-test i upareni uzorak t-test).

Analizom podataka utvrđeno je da je srednja ocjena (EG) prije i poslije programa iznosila 28,66 i 23,5. T-vrijednost tabele je 5,022, a statistička značajnost 0,001 - što je niže od nivoa značajnosti (P <0,05), pa se zaključuje da je razlika između prije i poslije pokazala značajne efekte aerobnih vježbi na postotak tjelesne masti kod ispitanica kontrolne grupe. Prema analiziranim podacima, srednja vrijednost post-testova u pogledu postotka tjelesne masti kontrolne grupe iznosila je 28,89, a eksperimentalne grupe 23,5. Statistička značajnost 0,002 i vrijednost t -987 u tabeli prikazuju značajnu statističku razliku indeksa tjelesne mase (P <0,05) kod ispitanica kontrolne i eksperimentalne grupe. Dobijeni rezultati su ukazali na to da su aerobne aktivnosti tokom četiri sedmice vježbanja imale značajan efekat na ispitanice sa prekomjernom težinom u smislu smanjenja postotka njihove tjelesne masti. Na osnovu dobjenih rezultata, preporučuje se da se žene sve više uključuju u fizičke aktivnosti i vježbanje.

Ključne riječi: *efekat, aerobno vježbanje, tjelesna kompozicija, prekomjerna težina, studenti, kvalitetniji život.*

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THE DIFFERENCES IN KINEMATIC PARAMETERS OF HAMMER THROW FINALISTS OF THE 2017 LONDON ATHLETICS WORLD CUP

RAZLIKE U KINEMATIČKIM PARAMETRIMA BACAČA KLADIVA FINALISTA SVJETSKOG ATLETSKOG PRVENSTVA U LONDONU, 2017.

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ABSTRACT

Hammer throw is motor-wise an extremely complex throwing discipline with the manifestation of several different forces that impede the rotational movement of the device and the thrower in the projected sagittal plane. Kinematic parameters are one of the segments when analyzing athletic disciplines, including hammer throw. This study aims to determine spatial and time differences of kinematic parameters between male and female hammer throw finalists at the 2017 Athletics World Cup in London. The study was conducted on a sample of 24 finalists of the 2017 Athletics World Cup in London, with the aim to analyze the differences in kinematic parameters between male and female hammer throwers. The results were acquired by applying the Independent Sample t-Test. It has confirmed the differences in most of the parameters, except those regarding ejection height (T=2,992; p<0,009), where it established statistically significant discrepancies between male and female finalists. On average, the male finalists threw a hammer from a height of 1,74±0,13m, and the female finalists from 1,54±0,17m. Based on the obtained results of kinematic parameters, it can be concluded that quantitative and qualitative differences in the measured kinematic parameters of the finalists in London are evident, but that statistically significant differences are recorded only in the ejection hight of the device.

Keywords: *elite athletes, kinematic parameters, hammer throw, differences*

INTRODUCTION

Hammer throw is a compound discipline of the acyclic type, intending to throw the device as far as possible following the propositions and rules of the discipline and the competition itself. The technique is characterized by very fast integrated rotations of the thrower and the device around the vertical axis in the sagittal plane, where the thrower and the device move from the rear to the front of the circle. During the rotational movement, the competitor and the device generate high kinetic energy at a maximum speed (> 27m / s) of short duration in the ejection phase (1.6s-2.2s). The span depends on how many turns the thrower performs. Hammer throwing affects the complete musculature of the thrower, primarily the musculature of the arms and shoulder girdle, strengthening the inner and outer ligaments of the dominant kinetic chains. Competitors develop and improve motor skills, especially coordination, speed, strength, and a sense of rhythm, the so-called. proprioception (Pavlović, 2020). Throwing disciplines require a higher degree of development of certain morphological dimensions, and often because of that, with insufficiently informed subjects, the prevailing opinion is that throwers, due to their constitution, are less efficient in expressing motor skills. This established opinion is misguiding because they all have a very high level of development and manifestation of motor skills during motor movement (Milanović, 1997), where the body with a different percentage makes an important segment of it. Muscle mass is dominant (53-56%), followed by bone mass (18-22%) and subcutaneous adipose tissue (15-19%). Based on the somatotype parameters, the hammer throwers match the meso-endomorphic somatotype. Compared to other athletes, hammer pitchers are characterized by a greater amount of muscle mass, and according to Sheldon's classification, they are closer to the mesomorphic type that correlates with successful results (Pavlovic, Radinovic, & Jankovic, 2012; Pavlovic, Rakovic, Radic, Simeonov, & Piršl, 2013). From the motor-functional aspect, hammer throwing is primarily initiated by explosive activation of agonist muscles. The initial activation is

followed by a period of relaxation and then deceleration due to the action of antagonist muscles as well as passive stretching of connective tissue with the integrated participation of individual motor skills. Hammer throwing is characterized by the maximum speed of movement through turns around the vertical axis in the sagittal plane until the moment of the ejection, which requires a sharp kinesthetic feeling, a high degree of motor skills, especially speed, coordination, excellent orientation during the turn, and a sense of rhythm Pavlović, 2016). In this regard, it was considered that four turns were performed by shorter and technically well-trained (faster) throwers, and three turns by stronger throwers. Today, both variants are found in all throwers, and the most common are throwers that perform four turns (Idrizović, 2010, Mihajlović, 2010). During the execution of the turn, a large centrifugal force develops and transmits to the thrower and tries to knock him down during the projected rotational movement. In order to block the fall and preserve the balance, the thrower leans to the opposite side of the device, thus creating the so-called counterweight, which means that the pitcher develops the force of the same intensity but of the opposite direction. The speed of movement of the caudal part of the body, at the end of the final stress, slows down, and the speed of the cranial part of the body increases in order to achieve a higher angular velocity of the system, i.e. the highest peripheral speed of the hammer at the moment of ejection (Pavlović, 2016). The size of the inclination of the body of the thrower on the opposite side of the hammer depends on the weight of the thrower, his physical fitness, and technical mastery. The greater the weight of the thrower, as well as their power, the lower the inclination. It would be ideal to preserve the vertical position of the body during the rotation, but this is almost impossible. This should be strived for because if the axis of rotation is left in the unchanged position, the lever rotation of the hammer increases, and in the final result, the flight distance of the device also increases (Stefanović, Bošnjak, 2011). From the biomechanical aspect, it is primary for hammer throwers to perform as high a speed as possible (through turns) in the shortest possible time interval within the limits of the support surface. In addition to the speed of rotation, the flight distance of the

hammer also depends on the initial flight speed, ejection angle, and height of the ejection point (Pavlović, 2016, Mercadante, Menezes, Martini, et al. 2007), of which the ejection speed proved to be the most important (Baronietz, Barclay, & Gathercole, 1997; Štuhec, Vertič, Čoh, 2008). According to researches (Maroński 1991; Bowerman, Freeman, & Vern Gambeta, 1998), increasing the ejection speed achieves a dramatic improvement in the range of any projectile throw, where increasing the velocity by 5% increases the results by 7 meters, and changing the angle by 5% only 60 centimeters. In addition to the effect of endogenous factors on the result of the throw, gravitational, centrifugal, and Coriolis forces also make a significant contribution. Using computer modeling for typical ejection heights and optimal hammer ejection angles, the influence of Earth rotation on hammer throw and the collision of the device with air currents, air pressure, temperature, altitude, and ground inclination (Mizera, & Horváth, 2002), presented practical guidelines for correction techniques, by which the results achieved at different latitudes or with different directions of release, can be corrected by a formula that includes the effect of earth rotation, which ultimately includes phenomena that affect the functional flow of the final speed of the device. Susanka, Stepanek, Miskos, & Terauds (1986) evaluated the path of the spatial trajectory of the hammerhead and the corresponding anthropometric points from the standpoint of individual turns, two-support and one-support phases and ejection phases, studying tangential and acceleration components as well as forces acting on the device. It was found that the positive factors cause an increase in the speed of the hammerhead, including several factors. With the help of three-dimensional cinematography, Dapena, & Mc Donald (1989) proved that, in relation to the system of the mass of the thrower, the trajectory of the angular momentum vector, the inclination of the body, and the height of the plane of the hammer are interrelated. As a result, during the turn, some pitchers tilt the torso back, holding the hammer handle high, while other keep the hammer handle low and lean forward. According to Dapena, Gutiérrez-Dávila, Soto, & Rojas-Ruiz (2003), the success in the hammer throwing results is a consequence of neutralizing

airflow resistance, assuming that the center of mass of the hammer coincides with the center of the ball. When throwing hammers, they use three-dimensional throwing data of male and female competitors through a simulation of a mathematical model. They proved that predicting the use of the right center of mass of the hammer reduced the deviations for men (2.39 ± 2.58m) and women (5.28 ± 2.88m), while predicting the effect of air resistance and the right center of mass of the hammer further reduced the deviations for men (-0.46 ± 2.63m), ie women's pitchers (1.16 ± 2.31m). Half of the distance loss produced by the air resistance was due to the action of forces on the ball, and the rest due to the forces exerted on the cable and the hammer handle. Increasing the force exerted on the hammer wire when turning is crucial for the throwing distance. Brice, Ness, Rosemond, Lyons, & Davis (2008) analyzed the five best hammer shots and compared the produced force acting on the hammerhead with the force measured using a stress apparatus. The results showed that the qualitative time-dependence of the two forces was basically the same, while the quantitative average difference between the measured and calculated forces during the five throws was 76N, which corresponds to a difference of 3.8% for the hammer wire force of 2000N. Also, Brice, Ness, & Rosemond (2011) analyze the relationship between force and linear velocity of a hammer wire when throwing by identifying the influence of the magnitude and direction of the force on the fluctuation of the hammer speed. The results showed a strong correlation between the decrease in linear velocity and the hammer wire force, where a strong correlation was found between the angle at which the hammer force lags in the radius of rotation towards its maximum and the magnitude of the hammer velocity decrease. Terzis, Spengos, Kavouras, Manta, & Georgiadis (2019) found that hammer throw efficiency is highly correlated with an athlete's lean body mass and higher bone mineral density, with over 66% (> 8000) of type IIa fibers in muscle structure, which is dependent on some other endogenous-exogenous factors (Ojanen, Rauhala, & Häkkinen, 2007; Judge, Bellar, McAtee, & Judge, 2010). A group of authors (Mercadante, Menezes, Martini et al. 2007) analyze the differences in kinematic parameters (angle, velocity,

ejection height, velocity-time curve) between Brazilian and international pitchers, starting with the 3D trajectory of the hammerhead. The results showed the inferiority of the Brazilian pitchers compared to the international in throwing speed (average 24.59m /s men and 23.59m /s women), international (average 29.60m /s men and 28.89m /s women). The velocity-time curves of the international pitchers compared to the Brazilian show that the acceleration is higher and the deceleration lower during turns. Konz, & Hunter (2015) conducted a survey on a sample of 13 elite American throwers and 16 elite throwers of the 2003 World Athletics Finals with the aim of determining differences in throwing technique between the sexes. The results confirmed that the weight and height of the athletes, the speed of the throws, some time components, and the centripetal force were different between the sexes. Panoutsakopoulos, Vujkov, & Obradović (2012) investigate the relationship between the duration and distance of hammer throwing with three and four turns, while the relationship between the duration of the throwing phases and the hammer throwing performance is examined by adequate correlations. The results showed that there is a high and strong correlation between the throwing time of the device and the throwing distance for throwers with 4 turns ($r = -83$; $p < 0.01$) and 3 turns ($r = -.96$; $p < 0.01$). On average, most pitchers spend more time in a single-support than in a two-support stance, where the inverse relationship of the throwing distance with the total turn duration is confirmed. The results of the study confirmed the differences in all defined parameters, while statistically significant differences were recorded only in the ejection speed ($p < 0.004$) and the fourth turn speed ($p < 0.002$) in favor of men. Men threw with an average throwing speed of 27.91m/s at an average turning speed of 4.67m/s, and women 27.17m/s, with an average turning speed of 4.03m/s. The consequences of differences can be sought in the length of training, different training process, the experience of competitors, morphological profile, motor and anatomical structures, movement techniques, biomechanical parameters that were not taken into account during the research. Based on the review of previous research, and following previous results, as well as possible positive or negative trends

in the development of this discipline from the aspect of qualitative and quantitative changes, the goal of current research has been defined. The aim of the research was to determine, record, and analyze possible statistically significant differences in the defined kinematic parameters between male and female hammer throw finalists of the 2017 World Athletics Championships in London.

METHOD OF WORK

The research sample includes 24 elite hammer throwing participants in the 2017 World Athletics Championships in London (12 male pitchers of average score 76.78 ± 1.65m and 12 women pitchers of average score 72.33 ± 3.29m) (Dinsdale, Thomas, & Bissas, 2018). The defined kinematic parameters of the finalist sample were taken from the IAAF official website (https://www.worldathletics.org/about-iaaf/documents/research-centre*), which confirms their originality and validity. For the purposes of the research, the following kinematic parameters of the hammer throwers were evaluated:

1. Starting speed (m/s)
2. Ejection speed (m/s)
3. Ejection height (m)
4. Ejection angle (°)
5. Speed increase through turns (m/s):
    a) Turn 1 (m s); b) Turn 2 (m/s); c) Turn 3 (m/s); d) Turn 4 (m/s)
6. Hammer path length (m):
    a) Turn 1 (m); b) Turn 2 (m); c) Turn 3 (m); d) Turn 4 (m)
7. Turn duration (s):
    a) Turn 1 (s); b) Turn 2 (s); c) Turn 3 (s); d) Turn 4 (s)

The data on the kinematic parameters of the finalists are presented in Table 1. The results obtained in the research are presented as arithmetic mean (Mean) and standard deviation (SD) by applying appropriate statistical procedures. The Independent Samples t-Test for small samples ($p < 0.001$) was used to obtain the necessary information regarding possible differences, while the statistical program Statistica 10.0 was used for data processing.

Table 1. *Kinematic parameters of male and female 2017 World Cup finalists in London (Dinsdale, Thomas, & Bissas, 2017).*

Result mean 76,78m	**Results (m)**	**Height of velocity (m)**	**Starting velocity (m/s)**	**Increase of velocity (m/s)**				**Release of velocity (m/s)**	**Angle of velocity (°)**	**Path of the hammer during turns (m)**				**Duration of turns (s)**			
				Turn 1	**Turn 2**	**Turn 3**	**Turn 4**			**Turn 1**	**Turn 2**	**Turn 3**	**Turn 4**	**Turn 1**	**Turn 2**	**Turn 3**	**Turn 4**
Fajdek	79,81	1,69	14,6	5,2	3,8	3,1	0,9	27,7	46,2	10,6	10,1	10,9	12,3	0,66	0,50	0,45	0,48
Pronkin	78,16	1,82	17,4	4,5	2,3	3,4	-	27,6	41,9	12,5	9,8	13,3	-	0,57	0,45	0,54	-
Nowicki	78,03	1,96	15,9	4,4	3,2	2,2	2,4	28,1	39,1	10,9	10,6	11,3	13,1	0,65	0,52	0,48	0,52
Bigot	77,67	1,57	16,7	4,7	2,1	1,5	2,5	27,6	39,7	9,76	10,6	11,3	13,1	0,54	0,48	0,42	0,50
Sokyrskii	77,50	1,57	14,7	6,3	3,7	1,8	0,9	27,4	40,9	10,9	11,4	10,8	8,3	0,64	0,52	0,44	0,44
Miller	77,31	1,76	16,7	4,5	2,5	1,8	1,8	27,4	42,1	11,2	10,4	10,4	11,2	0,61	0,48	0,44	0,46
Nazarov	77,22	1,86	15,6	5,7	2,2	1,5	1,9	27,1	43,0	10,3	10,7	10,6	13,3	0,60	0,51	0,46	0,54
Marghiev	75,87	1,83	15,3	5,0	2,5	1,3	2,9	27,1	42,3	9,7	10,0	10,4	11,7	0,57	0,48	0,45	0,48
Bareisha	75,86	1,64	15,1	5,1	3,7	2,0	1,3	27,2	44,7	11,3	10,0	10,5	12,8	0,66	0,47	0,43	0,51
Lingua*	75,13	1,58	13,6	5,9	3,0	2,2	1,6	27,3	39,5	10,7	11,0	10,8	10,6	0,72	0,58	0,49	0,44
Halasz	74,45	1,78	15,2	5,1	3,5	1,7	2,0	27,5	36,7	11,6	10,2	10,7	13,5	0,71	0,51	0,48	0,55
Baltaci	74,39	1,77	14,3	4,9	3,0	2,6	2,1	26,9	39,3	10,6	9,6	9,5	12,5	0,68	0,50	0,44	0,52
Result mean 72,33m	**Results (m)**	**Height of velocity (m)**	**Starting velocity (m/s)**	**Increase of velocity (m/s)**				**Release of velocity (m/s)**	**Angle of velocity (°)**	**Path of the hammer during turns (m)**				**Duration of turns (s)**			
				Turn 1	**Turn 2**	**Turn 3**	**Turn 4**			**Turn 1**	**Turn 2**	**Turn 3**	**Turn 4**	**Turn 1**	**Turn 2**	**Turn 3**	**Turn 4**
Wlodarczyk	77,90	1,80	16,1	4,3	2,6	1,6	3,5	28,3	41,8	11,2	10,0	10,9	12,1	0,64	0,49	0,48	0,48
Wang	75,98	1,85	17,5	4,3	2,4	1,5	2,2	28,0	38,5	10,4	9,5	9,7	11,5	0,55	0,44	0,40	0,45
Kopron	74,76	1,40	15,6	5,5	2,9	2,4	1,3	27,8	39,7	9,5	9,8	10,0	11,8	0,56	0,46	0,42	0,46
Zhang	74,53	1,24	15,6	4,9	3,1	2,3	1,7	27,6	41,6	11,3	11,1	10,9	11,8	0,64	0,52	0,46	0,46
Skydan	73,38	1,64	15,1	5,0	3,0	1,3	3,8	27,8	36,9	11,3	11,5	10,4	14,2	0,68	0,57	0,48	0,60
Fiodorow	73,04	1,41	16,7	4,5	2,0	1,6	2,9	27,8	39,2	10,9	9,5	10,3	10,9	0,60	0,44	0,44	0,44
Hitchon	72,32	1,54	15,6	5,5	3,0	1,9	0,9	26,9	40,3	10,4	9,6	9,4	13,5	0,58	0,45	0,40	0,53
Šafrankova	71,34	1,69	15,5	5,8	2,6	1,5	1,3	26,8	44,4	11,9	10,7	11,5	11,7	0,66	0,50	0,50	0,48
Price	70,04	1,27	15,1	3,6	2,9	2,2	2,9	26,9	38,5	11,1	9,4	9,4	11,1	0,67	0,48	0,42	0,46
Malyshik	69,43	1,48	15,2	5,5	3,0	1,6	1,3	26,7	42,9	9,7	11,0	10,1	12,9	0,57	0,53	0,44	0,52
Klaas	68,91	1,47	16,6	4,8	3,0	1,2	0,6	26,3	42,8	10,5	9,9	10,9	10,6	0,57	0,45	0,44	0,42
Tavernier	66,31	1,64	16,9	4,3	2,3	1,9	0,5	26,0	41,2	10,7	10,7	11,1	11,0	0,58	0,50	0,48	0,46

RESULT

Table 2. *Differences between kinematic parameters of Hammer throwers (WCh London, 2017)*

		Gender	Mean	t-value	p - (2-sided)	CI% -95,00-95,00
Starting velocity (m/s)		**Muale**	15,43±1,10	-1,520	0,144	-1,41 to 0,22
		Female	16,02±0,79			
Increase of velocity (m/s)	**Turn 1**	**Male**	5,11±0,59	1,011	0,321	-0,27 to 0,79
		Female	4,85±0,66			
	Turn 2	**Male**	2,96±0,63	1,069	0,303	-0,21 to 0,65
		Female	2,74±0,36			
	Turn 3	**Male**	2,09±0,65	1,526	0,143	-0,12 to 0,79
		Female	1,76±0,39			
	Turn 4	**Male**	1,11±2,63	0,990	0,348	-8,96 to 25,34
		Female	1,92±1,12			
Release of velocity (m/s)		**Male**	27,41±0,32	0,645	0,536	-0,32 to 0,62
		Female	27,26±0,72			
Angle of velocity (°)		**Male**	41,28±2,64	0,640	0,532	-1,42 to 2,68
		Female	40,65±2,19			
Height of velocity (m)		**Male**	1,74±0,13	**2,992**	**0,009**	0,06 to 0,34
		Female	1,54±0,17			
Path of the hammer during turns (m)	**Turn 1**	**Male**	10,84±0,77	0,251	0,801	-0,55 to 0,70
		Female	10,76±0,71			
	Turn 2	**Male**	10,37±0,52	0,554	0,597	-0,40 to 0,68
		Female	10,22±0,74			
	Turn 3	**Male**	10,88±0,90	1,484	0,155	-0,19 to 1,16
		Female	10,39±0,69			
	Turn 4	**Male**	12,04±1,54	0,189	0,859	-1,05 to 1,26
		Female	11,93±1,10			
Duration of turns (m/s)	**Turn 1**	**Male**	0,63±0,06	1,181	0,253	-0,02 to 0,07
		Female	0,61±0,05			
	Turn 2	**Male**	0,50±0,03	0,938	0,362	-0,02 to 0,05
		Female	0,49±0,04			
	Turn 3	**Male**	0,46±0,03	0,930	0,361	-0,02 to 0,04
		Female	0,45±0,03			
	Turn 4	**Male**	0,49±0,04	0,705	0,480	-0,03 to 0,05
		Female	0,48±0,05			

Abbreviation: Mean (average value), standard deviation (St.Dev), coefficient t-test (t-value), Sig.level (**p<0,001), CI% = confidence interval

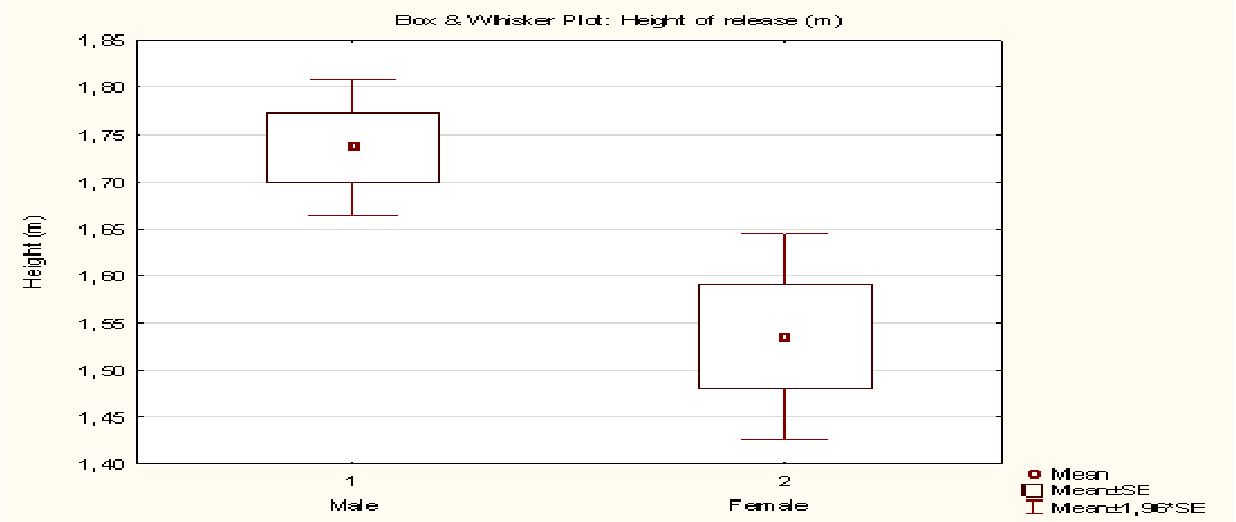

Figure 1. *The differences between finalists in* Height of release (m)

Analyzing the numerical values of the kinematic parameters, quantitative differences in all measured parameters between finalists of different sex were recorded (Table 2). Compared to men, female finalists achieved higher starting speed (16.02m/s), higher speed in the fourth turn (1.92m/s) and longer hammer path in the third turn (10.88 m), but shorter average turn duration (2.03s), as well as lower ejection angle (40.65 °). In the rest of the kinematic parameters, men showed better numerical values. Statistically significant differences were recorded only in the ejection height parameter ($T = 2.992$; $p < 0.009$) in favor of male competitors (1.74 m) versus female (1.54 m) (Table 2; Graph 1, 5). This was expected given the pronounced longitudinality within the morphological status of the male finalists. By the same token, female finalists with their lower longitudinality and lighter device, managed to perform the turns in a shorter time interval compared to men (Table 2). The average hammer ejection speed of the male finalists in London was 27.41 m/s, which is only 0.15 m/s faster than the female finalists, while the ejection angle was with a minimal difference (Table 1, 2 Fig. 1). The highest throwing speed was achieved by the third-placed Nowicki (28.1 m/s), who threw the hammer at an angle of 39.1 ° and a starting speed of 15.9 m/s,

which proved the inverse relationship between the speed and the ejection angle.

The individual starting speed of the male finalists ranged from 13.6 m/s (Lingua) to 17.4 m/s (Pronkin) and the ejection speed from 26.9 m/s (Baltaci) to 28.1 m/s (Nowicki). The male finalists entered the first turn at an initial velocity of 15.43 m/s, and 27.41 m/s at the moment of ejection. It turns out that during four turns, the speed increased by 11.98 m/s with significant oscillations in the speed in all turns. The speed increased with the number of turns, which is the goal of every hammer thrower, to achieve the maximum speed at the moment of ejection. The hammer was thrown with an average ejection angle of 41.3 °, ranging from a minimum of 36.7 ° (Halasz) to a maximum of 46.2 ° (first-placed Fajdek) (Tabela 1, Grafikon4). The men threw hammers from an average height of 1.74m, ranging from a minimum of 1.57m (Bigot, Sokyrskii) to a maximum of 1.96m (Nowicki). Male finalists achieved a longer average hammer path through turns (44.13m) of average duration (2.08s) compared to female finalists (43.30m) of 2.03s. More than 90% of the finalists achieved the average longest hammer path in the last fourth turn (Halasz 13.5m; Skydan 14.2m) (Table 1, 2, Graph 4, 5).

Among the female pitchers, the first-placed Wlodarczyk achieved the highest initial hammer ejection speed (28.3 m/s), at an ejection angle of 41.8 ° and a starting speed of 16.1 m/s. Also, the female finalists achieved a lower starting speed compared to the male finalists, ranging from 15.1m/s (Skidan, Price) to 17.5m/s (Wang) with a tendency to increase in the last turn. Also, women were inferior in terms of individual results of ejection velocity from 26.0 m/s (Tavernier) to 28.3 m/s (Wlodarczyk) and average initial velocity of 16.02 m/s (Table 2; Graph 4, 5). During the four turns, this speed increased by 11.24 m/s with significant oscillations in the speed of rotation, identical to the male finalists. The average ejection angle of women was 40.65 °, with a maximum of 44.4 ° (Shafrankova) and a minimum of 36.9 ° (Skydan).

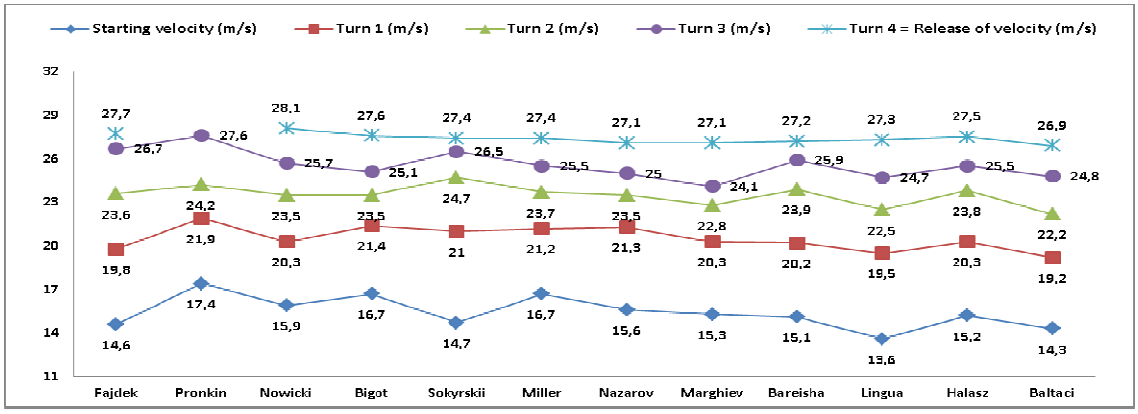

Figure 2. *Speed fluctuation during the turn (male finalists)*

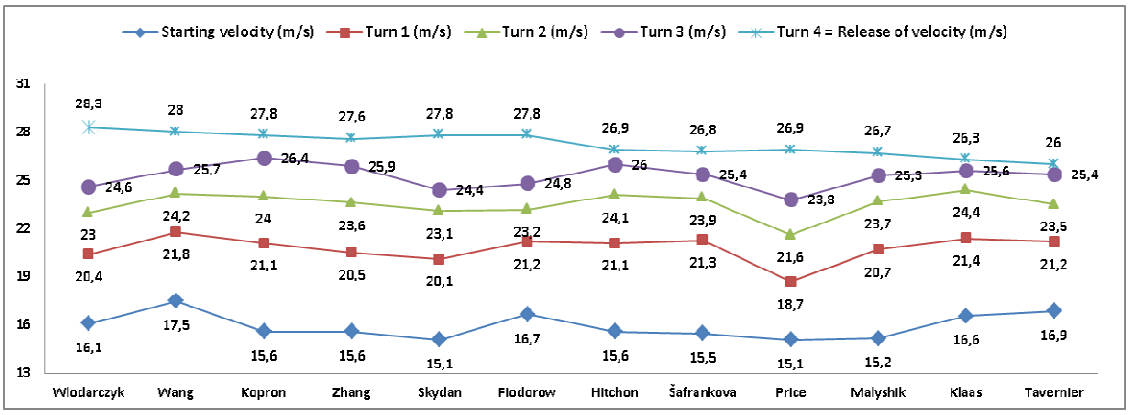

Figure 3. *Speed fluctuation during the turn (female finalists)*

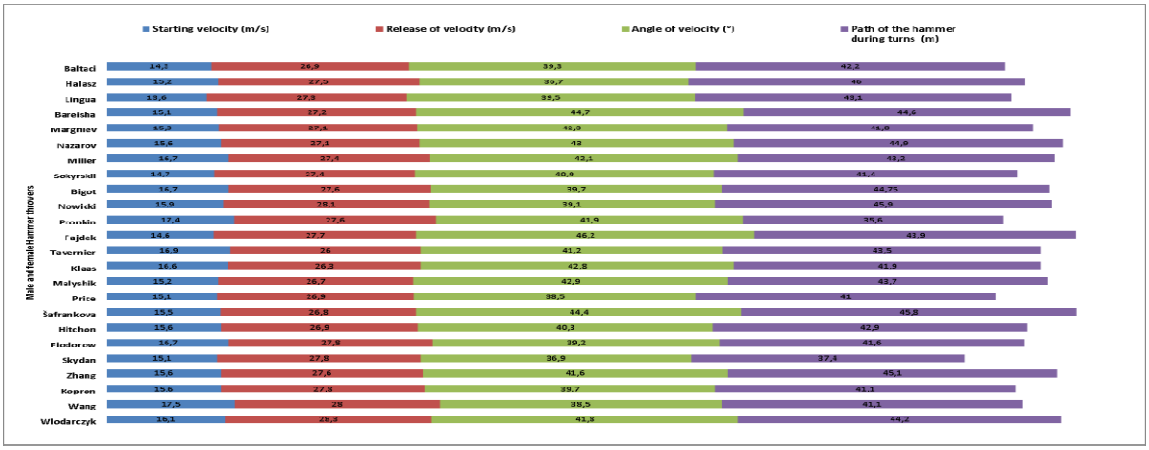

Figure 4. *Distribution of individual results of kinematic parameters of finalists (starting speed, ejection speed, ejection angle, hammer trajectory)*

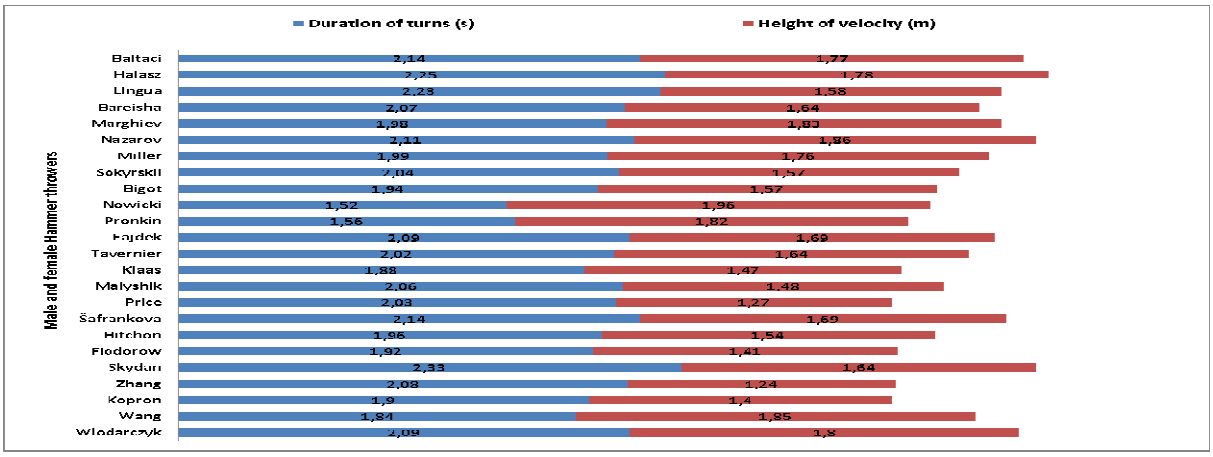

Figure 5. *Distribution of results of kinematic parameters of finalists (turn duration, ejection hight)*

DISCUSION AND CONCLUSION

The main goal of the research was to determine the differences of kinematic parameters between male and female finalists of the 2017 World Athletics Championships in London. The obtained results confirm significant differences between the sexes, representing the main result of the research.

However, a statistically significant difference was found only in the ejection height (Table 2, Chart 1).

Among throwing disciplines, hammer throwing is considered to be one of the most complex competitions in terms of coordination, technique, as well as the difficulties that arise in training and creating a correct dynamic stereotype. All of the previously mentioned requires the participation of different forces, the harmony of movement and depends on the components of the training process, continuous training, and years of experience (Judge, Bellar, Mc Atee, et al. 2010; Saad Fathallah Mohamed Elalem, 2016; Pavlović, 2020). The hammer throwing technique depends on achieving the maximum speed of the device through turns to the moment of the ejection, ejection angle, and ejection height. During the performance, there is an integrated rotary movement in the thrower – hammer interaction. It constantly rotates around an axis passing between the center of gravity of the thrower's body and the device, as well as through the support and the base (Maheras, 2009; Shesterova, & Rozhkov, 2018). Each movement begins with the

initial swinging of the thrower which creates the conditions for entering the first turn, whereby the thrower achieves the necessary rhythm and good concentration which is important for further stages of the technique. The number of turns performed primarily depends on the training of the thrower, his anatomical and physiological structures, and motor skills (Terzis, Spengos, Kavouras, et al. 2010). Then follow the swings where the competitor rotates together with the hammer around the vertical axis. During the hammer swing, the initial speed of rotation (12-16m/s) is noted and the common center of gravity of the system (thrower-hammer) must be within the surface of the support (Mihajlović, 2010; Pavlović, 2016). The results of the current research are in line with the above, where the average starting speed of the female finalists in London was 16.02m/s, and the male's 15.43m/s. Compared to the results of the research (Pavlović, 2020), men in London achieved a lower average starting speed by 1.26 m/s and women by 0.22s, than the finalists in Daegu. According to some authors (Panoutsakopoulos, Vujkov, Obradović, 2012; Konz, & Hunter, 2015) in the phase of overtaking the device, the movement of the thrower is mainly aimed at achieving the highest possible speed, when the thrower and hammer perform a complex rotational movement around vertical axes as one system. In doing so, they move together in the sagittal plane of the circular segment at maximum speed, in order to achieve the maximum speed of action on the device in the ejection phase (Štuhec, Vertič, & Čoh, 2008). The average ejection speed of the male finalists in London (27.41m/s) represents a better result than the female finalists (27.26m/s), but without statistical significance (Table 2). Compared to the male finalists in Daegu in 2011, the men's result is lower by 0.50m/s, while the women achieved a higher speed than the women's finalists in Daegu (by 0.9m/s). Although the differences in ejection speed are numerically small, they have a positive effect on the total throw length. The quality of the thrower's turn is highly correlated with the quality of coordination and records an increase in rotation speed with a linear increase in strong centrifugal force (more than 4000N) affecting the stability of the thrower and the projection of their trajectory. The thrower opposes the action of force by tilting the body backward with compensatory

movements of caudal extremities, lowering the center of gravity of the body (Pavlović, 2016). In order to perform the swing in as large a radius as possible, the thrower softly makes turns in the joints of the spine and hips so that when the hammer moves away from the body, the thrower moves the pelvic part of the body to the opposite side of the device, thus creating preconditions for the beginning of the second or third momentum (Idrizović, 2010; Mihajlović, 2010, Stefanović and Bošnjak, 2011; Pavlović, 2020). As both the thrower and device rotate, the speed of the device increases progressively until it reaches the moment of ejection at over 27 m/s and the perfect ejection angle 40°, though some throwers eject at the angle of 38° to 40° (Bowerman i et all. 1998; Konz i Hunter, 2015). However, some authors (Mihajlović, 2010, Stefanović and Bošnjak, 2011; Dapena, 1984) believe that the angle depends on the height of the athlete and ranges from 42 to 44 °, which is contrary to the results of this research. The average throwing angle of the finalists in London is 41°, with higher or lower individual values of the competitors, which is in line with the indications (Pavlović, 2020) and is inversely related to the height of the throwing device. It is known that hammer throwing is characterized by a complex spatio-temporal structure, with the aim of achieving a maximum speed of movement through swings and transition to 3, 4, or 5 turns, while moving linearly through the center of the circular segment. Such movement further complicates the changes in the spatial orientation of the planes that define the trajectory of the hammer in each turn (Gutiérrez-Davila, Soto, Rojas-Ruiz, 2002). Each pitcher goes through a two-support period (entry of the thrower into the turn) and a single-support period (exit of the thrower from the turn) in one turn. It is commonly believed that the acceleration of the hammer is achieved in the phase of two-support contact (traction force of the hammer directed downwards and forwards, which builds the stability of the thrower and achieves a higher speed), and not single-support (traction force of the hammer is very strong and the thrower opposes it by positioning their body opposite of the position of the device. Both phases are of very short duration (0.20-0.26s), and decrease as the thrower goes from the first to the fourth turn (Pavlović, 2020). During rotation, while the speed increases, the

distance between the feet decreases. The individual results of the finalists partially confirmed that the initial speed was 16m/s while at the moment of ejection the speed reached over 28m/s. Some coaches have tried to extend the two support phase to improve the score (30.31). The theory is proved by the marked fluctuation of the hammer speed in both two-support period and a noticeable decrease in the single-support period. However, Dapena, & McDonald (1989) question this theory, because they proved that the speed increases in the single-support period, believing that the impact of the thrower on the speed of the hammer is not negative, even when the thrower pulls the hammer towards the body because it comes from the highest point path. In our sample, there is a fluctuation of speed through turns, where the male finalists recorded a slightly higher average speed in the first, second and third turn (Turn 1 = 5.11m/s; Turn 2 = 2.96m/s; Turn 3 = 2 , 09m/s) in relation to women (Turn 1 = 4.85m/s; Turn 2 = 2.74m/s, Turn 3 = 1.76m/s), and the fourth turn is dominated by women's finalists (Turn 4 = 1.92m/s). These results are in contrast to the results of the finalists in Daegu, 2011, where women had a higher turning speed (Pavlović, 2020). They are a consequence of the different synchronization of the neuro-motor activity of the thrower, proprioception, the length of the levers, and the weight of the device. According to some researchers (Pavlović, 2016; Mihajlović, 2010, Stefanović and Bošnjak, 2011), the turning of the hammer begins at the moment when the device is on the right side of the thrower, below shoulder height. At the moment of passing over the arch of the left foot, the speed of the hammerhead is the highest, and thus the strongest centrifugal force, which requires the inclination of the thrower to maintain an equilibrium position. When entering the first turn, the shoulders and hips are parallel. However, when exiting the turn and moving to the one-support period, the hips move faster, overtaking the device, in order to achieve the fastest possible two-support period, and completing the first turn, generates a large torque (Dapena, Mc Donald, 1989). In this phase, the thrower strives to achieve the best anatomical-biomechanical parameters for the most efficient and most favorable entry into the next turn by synchronized myometric-plyometric muscle contractions through

kinetic muscle chains. Thus, the hammer must enter the second turn at a higher speed than the entry into the first, which was confirmed by the results of this survey of the finalists in London (Table 2, Graph 2.3). The same principle is applied when entering and exiting the next three or four turns. This theory was confirmed in our study for both subsamples, where, from turn to turn, after the starting speed of about 16m/s, the ejection speed increased by 11m/s successively, reaching the maximum speed in the fourth turn in the ejection phase (Table 1, Graph 2 , 3, 4), which is in line with the research [Štuhec, Vertič, Čoh, 2008; Pavlović, 2020].

Men in London had a higher average speed increase through turns (11.43m/s) than women finalists (11.24m/s) and were also more successful than finalists in Daegu, 2011 (men 11.22m/s; women 10, 93m/s). However, on average, male and female finalists in Daego achieved higher starting and ejection speed than the London finalists, which resulted in a better ranking.

The movement of the hammer starts with several swings which are followed by turns in which the thrower rotates synchronously. The speed of the hammer is constantly increasing until the moment of ejection (Maheras, 2009). What is then being observed is the circular motion of the hammer around the thrower, the gradual change in the inclination of the plane of motion of the hammer, and the horizontal trajectory of the thrower-hammer system within the circle. In the initial part of the throw, the hammer is in a horizontal trajectory of 37 ° (Stefanović, Bošnjak, 2011), but it becomes steeper as the speed increases and reaches an inclination of about 40 ° during the last turn. The pitcher keeps the hammer on its circular trajectory while, during the last turn, the centrifugal force is transmitted through the wire to the center of the ball. During the turn, the wire acts equally and opposite to the force of the thrower's hands, which tends to pull him forward (Dapena, McDonald, 1989; Mihajlović, 2010; Brice, Ness, Rosaemond, 2011). The duration of turns of elite throwers depends on the number of turns and the increase in speed, ranging from 1.64 sec. (with 3 turns) up to 2.16 sec. (with 4 turns). For example, when achieving results over 80m, Murofushi performed 4 turns in 1.96 sec, Tikhon in 2.04 sec, etc. The ejection speed, if achieved at the appropriate angle,

is almost always a decisive factor in the final result (Pavlović, 2016; Idrizović, 2010). The first-place winner in London (Fajdek, 79.81 m) threw a hammer at a speed of 27.7 m/s at an angle of 46.2 °, while the female winner did the same (Wlodarczyk 77.90 m) at a speed of 28.3 m/s and an angle of 41, 8 °. The inverse relationship between the ejection speed and the ejection angle was present at all times. The research results of the 2011 Daego World Championship finalists confirmed that the ejection speed is inversely related to the ejection angle.

When throwing hammers, the action on a longer path is not a guarantee of a good result, but it is necessary to achieve the maximum force in the shortest time interval (Panoutsakopoulos, Vujkov, Obradović, 2012), which is confirmed by this research (Table 1). Each sex has characteristics that contribute to success because there are distinct anthropometric differences between them probably affect the optimal technique (Konz and Hunter, 2015), which can be confirmed in the results of this research. The most visually noticeable differences are in height and body weight, where male hammer throwers are typically taller and have a higher mass than their counterparts (Pavlović, et al. 2012; Pavlović, et al. 2013). The male hammer is proportionally more massive than the female hammer which results in a different manner of overcoming the force of inertia and centrifugal force. Therefore, female pitchers have a higher starting speed due to lower body weight, shorter torso, and lower ball weight, as well as the center of mass of rotation due to the difference in weight and mass distribution during turns and throws (Bartonietz, Barclay, Gathercole, 1997; Dapena, Gutiérrez-Dávila , Soto, & Rojas-Ruiz, 2003; Knudsson, 2003), which was also confirmed in this study, where women had on average a higher starting speed (16.02m / s) than men (15.43m / s) so they need less effort than men when confronting forces of inertia and centrifugal force (Ransdell, & Well, 1999; Bartonietz, 2004; Dapena, 1986).

The research was conducted on a sample of 24 finalists of the World Athletics Championships in London in 2017, with the aim of determining the differences in kinematic parameters between male and female hammer throwers. The results of the research confirmed the differences in all defined parameters, while statistically

significant differences of the finalists were recorded only in the ejection hight ($T = 2.992$; $p < 0.009$). Male finalists achieved a higher ejection height (1.74 ± 0.13m) than female finalists (1.54 ± 0.17m). The results obtained in this study are partially consistent with the results of some previous studies, and depend on the parameters being analyzed.

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THE DIFFERENCES IN KINEMATIC PARAMETERS OF HAMMER THROW FINALISTS OF THE 2017 LONDON ATHLETICS WORLD CUP

SAŽETAK

Bacanje kladiva je motorički vrlo kompleksna bacačka disciplina sa manifestacijom više različitih sila koje nastoje da onemoguće rotaciono kretanje sprave i bacača u projektovanoj sagtalnoj ravni. Kinematički parametri su jedan od segmenata u analizi atletskih disciplina, uključujući i bacanje kladiva. Cilj studije bio je da se utvrde prostorne i vremenske razlike kinematičkih parametara između muških i ženskih finalista, bacača kladiva Svjetskog prvenstva u Londonu. Studija je sprovedena na uzorku 24 finalista Svjetskog prvenstva u Londonu, 2017, sa ciljem analize razlika kinematičkih parametara između muških i ženskih bacača kladiva. Da bi se dobili potrebni rezultati primenjen je t-test za male nezavisne uzorke. Rezultati su potvrdili razlike u većini mjerenih parametara ali statistički značajne razlike između muških i ženskih finalista su potvrđene samo u visini izbačaja (T=2,992; p<0,009). Muški finalisti su bacali kladivo u prosjeku sa visine 1,74±0,13m, a žene sa 1,54±0,17m. Na osnovu dobijenih rezultata kinematičkih parametara može se zaključiti da su evidentne kvantitativne i kvalitativne razlike u mjerenim kinematičkim parametrima finalista u Londonu, ali da su statistički značajne razlike evidentrane samo u visini izbačaja sprave.

Ključne riječi: *elitni sportisti, kinematički parametri, bacanje kladiva, razlike.*

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STRENGTHENING AND STABILIZATION EXERCISES IN PREVENTION OF SHOULDER INJURIES

VJEŽBE ZA JAČANJE I STABILIZACIJU U PREVENCIJI POVREDE RAMENA

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ABSTRACT

The shoulder joint is the most flexible joint in the human body which experiences high loads during certain sport activities involving overhead motion. Overhead athletes experience rapid shoulder elevation, abduction and external rotation during the movement and rapid deceleration after the movement, making them susceptible to shoulder injuries. Due to the extreme ranges of motion, overhead athletes tend to develop increased external rotation, combined with decreased range of internal rotation, emphasizing the need for balanced shoulder care program in the training process to prevent such occurrences. The aim of the research paper was to develop training regimen for injury prevention and shoulder maintenance that can be incorporated in daily training activities of the athletes in order to decrease the occurrence of injuries. Three part training program was designed consisting of specific warm up, strengthening and stabilization exercises and stretching exercises. The aim of the specific warm up was to prepare the shoulder for the training loads, mimicking the overhead movements and stimulating the stabilization in the joint. Strengthening and stabilization exercises aimed to strengthen external rotators in the shoulder and improve the stabilization of the shoulder joint by targeting specific muscles such as serratus anterior. The focus of stretching exercises was to stretch internal rotation muscles, which experience high loads in the overhead athlete's training. An effective training program that can be performed with minimal equipment and in a short time frame was designed to enable its simple incorporation into the daily training of overhead athletes.

Keywords: *shoulder, overhead athlete, shoulder injuries, injury prevention.*

STRENGTHENING AND STABILIZATION EXERCISES IN PREVENTION OF SHOULDER INJURIES

INTRODUCTION

The shoulder joint is the most flexible joint in the human body which experiences high loads during certain sport activities involving overhead motion. Overhead athletes experience rapid shoulder elevation, abduction and external rotation, making them susceptible to shoulder injuries. Apart from the throwing motion itself, deceleration of the arm segment after the movement significantly contributes to injuries as well. Since overhead athlete requires a delicate balance between shoulder mobility and stability, regular stretching, strengthening and stabilization exercises must be balanced in a year-round training.

Due to special loads on the athlete's shoulder, researchers have observed that anatomical changes of overhead athlete's arm are sometimes inevitable in order to increase the maximum external rotation. Baseball pitchers demonstrated up to 21° more external rotation at 90° abduction than other players on the team (Johnson, 1992). To achieve this extreme external rotations, some range of motion loss in internal rotation is to be expected.

Manske, Wilk, Davies, Ellenbecker and Reinold (2013) defined a loss of up to 18 - 20° of internal rotation with no total range of motion loss, as normal anatomical changes consistent with repetitive overhead motion.

Therefore, regular assessment of athlete's shoulder and maintenance of the joint's flexibility and strength is required to prevent injuries.

Reinold, Gill, Wilk and Andrews (2010) list six principles of injury prevention and treatment programs: maintaining range of motion, maintaining strength of the glenohumeral and scapulothoracic musculature, emphasizing dynamic stabilization and neuromuscular control, core and lower body training, off-season preparation and in-season maintenance. Development of the injury prevention program followed the before mentioned principles, previous research in the field and personal experiences with effectiveness of exercises as part of the training program.

Specific muscles, known to contribute to shoulder problems were targeted by the training program to minimize the occurrence of injuries. Three part training program was designed consisting of specific warm up, strengthening and stabilization exercises and stretching exercises. The aim of the specific warm up

was to prepare the shoulder for the training loads, mimicking the overhead movements and stimulating the stabilization in the joint.

The focus of stretching exercises was to stretch internal rotation muscles, which experience high loads in the overhead athlete's training. Effective training program that can be performed with minimal equipment and in a short time frame was designed to enable its simple incorporation into the daily training of overhead athletes. Strengthening and stabilization exercises for overhead athlete have been thoroughly researched by Wilk, Meister and Andrews (2002).

Among various exercises, push up plus in external rotation position has been proved as highly effective shoulder stabilization exercise by Cho et. al. (2014) and Lee, Lee and Park (2013). It has been confirmed to be most effective when performed on the floor in a standard position by Ludewig, Hoff, Osowski, Meschke and Rundquist (2004).

Our training program included the recommended exercises by these researchers. The importance of the stretching regimen was emphasized in research of Lintner, Mayol, Uzodinma, Jones and Labossiere (2007). Recommended stretching techniques for overhead athletes include sleeper stretch and cross-body stretch (Manske et al., 2013 and Laudner, Sipes and Wilson, 2008). Manske, Meschke, Porter, Smith and Reiman (2010) included posterior joint mobilization techniques with cross-body stretch, which proved even more effective.

The stretching regimen of our tree part program followed the recommended guidelines by previous researchers.

MATERIALS AND METHODS

Existing research in the field of injury prevention and shoulder care in overhead athletes has been obtained from PubMed Central and Google Scholar. Meta-analysis of the material was performed and shoulder exercises that demonstrated positive correlation with improved shoulder health were used as a building blocks for the training program. Reviewed research papers included male and female subjects of different quality levels (rating from high-school athletes to professionals). The subjects were young adults, participating in regular sports activity. A preventive training program for overhead athletes was consequently designed based on the findings of the previous researchers and personal experiences with injury prevention exercises for shoulder joint.

RESULTS

Based on the previous research and personal experiences a three phase preventive training program has been designed. It includes specific warm-up for the shoulder, stabilization and strength exercises for antagonists of the athlete's throwing motion and stretching exercises for agonist muscles used in the motion.

An established set of exercises should be used as an addition to daily training plan, requiring minimum equipment and allowing individual intensity adjustment. The training program is condensed in a short unit that can be performed in 30-40 minutes and is therefore viable as a regular addition to daily routine in the overhead athlete's training.

Repetitive training loads and similar movement lead to constant overloading of the same muscle groups. The proposed set of exercises should therefore be performed regularly in order to ensure preventive function of the exercises and flexibility-strength ratio in the shoulder muscles.

The complete training program is represented in the Table 1 below:

Table 1. *Training program for shoulder injury prevention in overhead athlete*

WARM UP		
15 min		Full body aerobic activity such as running
2-3 sets	10 repetitions	• Forward crawl • Backward crawl • Bunny hops • Shoulder rotations with free weights in sagittal plane (Figure 1) • Shoulder rotations with free weights with both hands circling in the same direction in a sagittal plane
STRENGTH AND STABILIZATION EXERCISES		
3-4 sets	10 repetitions	• External rotation (Figure 2), • Standing external rotation with elastic bands (Figure 3), • Throwing motion imitations in reverse (Figure 4), • Push up plus (Figure 5) • Horizontal abduction in prone position (Figure 6).
STRETCHING EXERCISES (performed as a separate unit after a training session)		
1-3 sets	30 seconds (three increases in position every 10 seconds)	• Sleeper stretch (Figure 7) • Cross-body stretch (Figure 8)

STRENGTHENING AND STABILIZATION EXERCISES IN PREVENTION OF SHOULDER INJURIES

Detailed explanation of the training program for shoulder injury prevention in overhead athlete by section:

WARM-UP

The warm up routine consists of dynamic exercises including full range of motion in the shoulder. Thorough general warm-up should be performed before specific shoulder exercises in this program (running, etc.). Exercises include forward crawl, backward crawl, bunny hops and shoulder rotations with free weights in sagittal plane (Figure 1), which can be followed by shoulder rotations with free weights with both hands circling in the same direction in a sagittal plane (advanced athletes). The exercises should be performed in 2-3 sets of 10 repetitions. Forward crawl, backward crawl and bunny hops should be performed on a flat, clean non-slippery surface, while shoulder rotations with free weights require the athlete to stand upright on a flat surface.

Description of the exercises:

Forward crawl: Athlete crawls on all fours in forward direction, keeping contact with the floor with their hands and feet.

Backward crawl: Athlete crawls on all fours with legs in the front, keeping contact with the floor with their hands and feet.

Bunny hops: Athlete performs bunny hops from both legs, switching the floor contact phase from hands to legs and back while moving forward.

Shoulder rotations with free weights in sagittal plane: Athlete stands upright and rotates with a free weight of appropriate weight in sagittal plane. Circling is performed with one hand. Athlete's aim is to perform the rotation in shoulder joint and avoid excessive bending in the elbow joint.

Shoulder rotations with free weights with both hands circling in the same direction in a sagittal plane (advanced athletes): This exercise is an advanced version of previous exercise, aimed at better prepared athletes. Athlete stands upright and rotates with free weights in both hands in a sagittal plane. Both hands simultaneously move forward or backward. Athlete's aim is to perform the rotation in shoulder joint and avoid excessive bending in the elbow joint.

STRENGTH AND STABILIZATION EXERCISES

Strength and stabilization exercises should be performed during training (ideally as a part of the routine preparation for the training session including overhead motion) or as a separate training session. The preventive training for overhead athletes includes strengthening of the upper back and shoulder muscles to increase scapular stabilization (serratus anterior) and shoulder's external rotator's strength (infraspinatus and teres minor) to contradict the strong internal rotators. The aim of the strengthening exercises is to achieve balance in strength of agonists and antagonists and therefore prevent possible injuries due to muscular imbalance. Stabilization exercises, such as push up plus add important element of proper muscle activation and protection of the joint.

Strength and stabilization exercises in this training program include:

External rotation (Figure 2), standing external rotation with elastic bands (Figure 3), throwing motion imitations in reverse (Figure 4), push up plus (Figure 5), and horizontal abduction in prone position (Figure 6).

The order of the exercises performed can vary and should be done in fluid motion in 3-4 sets of 10 repetitions, with 1 minute rest. Different strength elastic bands or free weights should be used to adapt the training according to the athlete's needs.

Description of the exercises:

External rotation: Athlete stands upright with elbow by his body. The rubber band of appropriate thickness is attached to stable surface parallel to the athlete. The athlete performs external rotation with bent elbow joint while keeping elbow close to his body. A rolled towel can be placed between the athlete's body and his elbow to maintain stable and static position of the elbow during the exercise. The rubber band is then slowly returned to the starting position.

Standing external rotation with elastic bands: Athlete stands upright, holding the ends of a rubber band of appropriate thickness in his hands. His arms are by his body with bent elbows. Athlete slowly proceeds to stretch the rubber band in the opposite directions, performing external rotation with both arms simultaneously. The rubber band is then slowly returned to the starting position.

Throwing motion imitations in reverse: A rubber band of appropriate thickness is

attached to the stable object in front of the athlete. Athlete holds the rubber band in front of him and by pulling it backwards stimulates the throwing motion in reverse. The rubber band is then slowly returned to the starting position.

Push up plus: Athlete starts in the push up position. He performs the downward movement with his chest while maintaining straight arms, using serratus anterior muscle to cause an outward rotation of the scapula. Athlete then returns to the starting position.

Horizontal abduction in prone position: While lying on his stomach, the athlete performs horizontal abduction with straight arm. Appropriate heavy weights should be used as a resistance. Athlete returns to the starting position and repeats the motion without touching the floor during the set.

STRETCHING EXERCISES

Research articles in the field of stretching have found acute decreases in strength following stretching and it is therefore recommended that stretching exercises should be performed at the end of a workout or as a separate workout.

Recommended stretching techniques for overhead athletes concentrate on increasing internal rotation of the shoulder and maintaining functional length of the subscapularis.

Stretching exercises included in the training program are sleeper stretch (Figure 7) and cross-body stretch (Figure 8).

Sleeper stretch: Athlete performs the stretch while lying on his hip. Elbow joint should be bent at 90 degrees with the palm of the hand facing towards the floor and elbow resting on the floor. Slow movement of the palm of the hand towards the floor is stimulated by the free arm. The aim of the exercise is to improve the internal rotation of the shoulder by targeting infraspinatus and the teres minor muscles. The stretch should last 30 seconds with the free arm pushing the wrist and the palm of the hand a bit further towards the floor every 10 seconds.

Cross-body stretch: Cross-body stretch accompanies the sleeper stretch as exercise that improves internal rotation and horizontal adduction's range of motion in the overhead athlete. Cross-body stretch is performed with the athlete lying on the floor with the arm bent at 90 degrees

towards the body. Free hand slowly moves the arm from one side of the body towards another. The stretching position should be held for 30 seconds, which is considered an optimal time frame. A static technique with three increases of the position every 10 seconds is recommended.

DISCUSSION AND CONCLUSIONS

Overhead athletes experience rapid shoulder elevation, abduction and external rotation, making them susceptible to shoulder injuries. Muscle balance and appropriate flexibility of the joint is therefore necessary to prevent them. After a thorough review of the available research, a set of preventive exercises has been developed. The training program is designed to maintain the length of internal rotators and strengthen external rotators of the shoulder, preventing possible injuries due to muscular imbalance. The established set of exercises should be used as an addition to daily training, requiring minimum equipment and allowing individual intensity adjustment. It has been concluded that in order to ensure the preventive function of the exercises, the developed set of exercises must be performed regularly. The proposed exercises can be improved by different variations, specific to the athlete's discipline (javelin throw, baseball, rugby, etc.), further developing the individuality of the proposed program. Better athletes can advance to more dynamic execution of the exercises (throwing balls instead of pulling the elastic band). Researchers have observed two potential possibilities to further expand the research: Viability of the static stretching exercises such as sleeper stretch and cross-body stretch could be further analyzed in comparison to the dynamic alternatives due to dynamic nature of the overhead sports and high training loads. Additionally, various combinations and variations of different exercises could result in different outcomes and could be further analyzed.

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FIGURES AND ILLUSTRATIONS

Figure 1. *Shoulder rotations with weigths in sagittal plane free*

Figure 2. *External rotation*

Figure 3. *Standing external rotation withn elastic bands*

Figure 4. *Throwing motion imitations in reverse position*

Figure 5. *Push up plus*

Figure 6. *Horizontal abduction in prone*

Figure 7. *Sleeper stretch*

Figure 8. *Cross-body stretch*

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ABSTRACT

The shoulder joint is the most flexible joint in the human body which experiences high loads during certain sport activities involving overhead motion. Overhead athletes experience rapid shoulder elevation, abduction and external rotation during the movement and rapid deceleration after the movement, making them susceptible to shoulder injuries. Due to the extreme ranges of motion, overhead athletes tend to develop increased external rotation, combined with decreased range of internal rotation, emphasizing the need for balanced shoulder care program in the training process to prevent such occurrences. The aim of the research paper was to develop training regimen for injury prevention and shoulder maintenance that can be incorporated in daily training activities of the athletes in order to decrease the occurrence of injuries. Three part training program was designed consisting of specific warm up, strengthening and stabilization exercises and stretching exercises. The aim of the specific warm up was to prepare the shoulder for the training loads, mimicking the overhead movements and stimulating the stabilization in the joint. Strengthening and stabilization exercises aimed to strengthen external rotators in the shoulder and improve the stabilization of the shoulder joint by targeting specific muscles such as serratus anterior. The focus of stretching exercises was to stretch internal rotation muscles, which experience high loads in the overhead athlete's training. An effective training program that can be performed with minimal equipment and in a short time frame was designed to enable its simple incorporation into the daily training of overhead athletes.

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MAXIMUM ISOMETRIC MUSCLE STRENGTH AS A PREDICTOR OF ONE REPETITION MAXIMUM IN THE SQUAT TEST

MAKSIMALNA IZOMETRIJSKA MIŠIĆNA SILA KAO PREDIKTOR JEDINOG MAKSIMALNOG NAPRZANJU U TESTU ČUČANJ

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ABSTRACT

This study aims to determine whether maximum isometric muscle strength, exerted at a certain angle in the knee joint (80 °, 110 °, and 140 °), may be used as a predictor of 1RM in the squat movement task. A group of twenty-four male students (N = 24) took part in the research in 2 separate sessions and 7 days of rest between each. In the first session, the anthropometric measurements and assessment of muscle strength, that is 1RM, were measured by maximum repetition to failure method on the Smith machine. The maximum isometric force (Fmax) of the leg muscles was measured by the Alternating Consecutive Maximum Contraction Test in laboratory conditions on a Smith machine using a dynamometer probe and the Globus Ergo Tesys System 1000 software system. Analyzing the results based on linear regression, the authors conclude that, with an accuracy of 84.5%, we can estimate 1RM in the squat exercise measuring the maximum isometric force exerted at an angle in the knee joint of 140 °. The results obtained by this research can be used in practice when assessing 1 RM based on the measurement of the maximum isometric force for a given movement task.

Keywords: *muscle strength, prediction, 1RM, squat*

MAXIMUM ISOMETRIC MUSCLE STRENGTH AS A PREDICTOR OF ONE REPETITION MAXIMUM IN THE SQUAT TEST

INTRODUCTION

The squat is a conventional exercise that improves muscle strength and the strength of the lower extremities. Also, it is used as an assessment tool when assessing the previously mentioned myogenic abilities. Muscle force testing provides significant kinematic parameters that are key for programming strength and power training, and based on the given parameters, the effects of a training model are assessed (Herman 1990, Hakinen 1994). However, one of the fundamental goals of muscle strength testing in sports is to estimate the maximum voluntary muscle force in static or 1 RM (maximum repetition) in dynamic conditions. Maximum voluntary muscle force, or muscle strength, is the maximum force that a muscle or group of muscles can generate when overcoming large external loads at low speeds of muscle contraction or in isometric conditions (Zaciorsky and Kreamer, 2009). Isometric conditions represent the manifestation of voluntary muscular (isometric) force, with a constant angle in the joint of the corresponding limb (Petrović, Kukrić, Dobraš, and Zlojutro, 2019). Furthermore, 1 RM represents the manifestation of maximum muscular force in dynamic conditions, that is the maximum load that can be overcome by the appropriate technique only through one repetition. 1 RM can be estimated directly or indirectly through a number of repetitions based on % 1RM with the submaximal load. Direct measurement requires lifting heavy loads and is therefore not recommended to be performed with less trained individuals due to the high risk of injury. Indirect assessment of 1 RM and the testing of maximal voluntary muscle contraction have emerged as a safer option for the health of the subjects. The reliability coefficient of the tests that assess muscle strength by the indirect method, ie by applying a specific test of repeated (repetitive) maxima (RM) is in the range from r = 0.92 to 0.98 (Sale, 1991; Carpinelli, 2011). Researches have shown that the isometric dynamometry method is also highly reliable. A number of researchers have obtained high test reliability when measuring maximum isometric squat muscle force (Kawamori et al., 2006; Beckham et al., 2012; Comfort, Jones, McMahon, & Newton, 2015; Haff, Ruben, Lider, Twine, & Cormie, 2015; Thomas, Comfort, Chiang, & Jones, 2015).

Thus, there appears to be a scientific basis that supports the use of testing methods, that is the estimation of maximal muscle force under isometric and dynamic conditions of 1RM. However, the question arises whether it is possible to predict the maximum muscle force in dynamic conditions based on the kinematic parameters obtained by the maximum voluntary muscle contraction in isometric conditions. The fact that justifies such assumptions is that the maximum muscle force achieved in slow motions does not differ significantly from the maximum muscle force of motion in isometric conditions (Smidtbleicher 1992; Zaciorski and Kreamer 2009; Lum et al., 2020). Furthermore, the results of several studies (Blazevich et al., 2002; Nuzzo et al., 2008; Demura et al., 2010; Caleb et al., 2015) showed a significantly high correlation between isometric squat and 1 RM in the squat test. Nevertheless, there are different scientific opinions when it comes to the angle in the knee joint when testing the maximum isometric force, ie the prediction of 1RM based on the maximum force exerted at a certain angle. Studies show that higher joint angles of 90 ° -160 ° are more suitable for estimating Fmax in the last squat (Marchetti et al., 2016). Sale (1991) proposes that isometric measurements be performed in the position in which the force is the greatest for a given range of motion.

This study aims to determine whether the manifestation of maximum isometric muscle force at a certain angle in the joint (80 °, 110 °, and 140 °) can be used as a predictor of 1RM in the squat exercise.

METHOD

The study sample consisted of twenty-four first-year male students from the Faculty of Physical Education and Sport at the University of Banja Luka. All examinees were male, healthy, physically active, and did not have any intense physical activities 72h prior to testing. In order to reduce errors in conducting the experimental procedure, selected examinees who were trained to lift weights and use weight machines. The tests

were performed at the Institute of Sports at the Faculty of Physical Education and Sports, at the University of Banja Luka.

All measurements were carried out in two separate sessions with seven days of rest between them. Familiarization with the experimental protocol, anthropometric measurements, and the assessment of 1RM in the squat exercise was done in the first session. The measurement of the maximum isometric force of leg muscles exerted in three different knee joint angles in the squat movement was executed in the second session.

After the familiarization with the experimental protocol, the respondents started with the anthropometric measurements. Anthropometer and body analyzer (TANITA BC - 418MA, Tokyo, Japan) were used for anthropometric measurements. The measurement of anthropometric variables was conducted according to the International Biological Program (IBP), and in this paper, these have been used: body height, body mass, muscle tissue percentage, fat tissue percentage, MFR-index (the ratio between muscle and fat tissue in the body). All measurements were performed according to the ACSM´s protocol.

The assessment of muscle force, that is 1RM, was carried out using the training-to-failure method on a Smith machine. The respondents were asked to lift a load of a given weight the maximum number of times, with the number of repetitions not exceeding 10. The approximate muscle force value was obtained based on the regression equation 1RM = weight / (1.0278 - (0.0278 * number of repetitions)) according to Brzycki (1993) and Carpinelli (2011). After a ten-minute warm-up, all the respondents did 2 sets with 5 repetitions of the additional warm-up session of squats, with the load of 70 and 90 kg. In the third set, the weight was progressively increased by 10% for the measurer to predict the optimal weight for the test. If the respondent, due to poor estimation of the meter, succeeded in lifting the given weight more than 10 times in the fourth series, the task would be interrupted only to be continued after a ten-minute break in the fifth series where additional load would be added.

The maximum isometric force of leg muscles was measured using the Alternating

Consecutive Maximum Contraction Test in laboratory conditions (Suzović, 2008 and Suzović et al., 2015) on the Smith machine using a dynamometer probe and the Globus Ergo Tesys System 1000 software system. The respondents performed two maximum voluntary contractions 3-5 seconds long with a one-minute break between the repetitions. The three angles of the knee joint of 80°, 110°, and 140° were measured using the Leica Vetronix - SG12F goniometer. The respondents were asked to perform every repetition from the same initial position. They were, also, asked to place their feet in the width of the hips and to perform the maximum possible muscular effort. The dynamometer was fixed to the ends of the machine used, with the fixers specifically designed for this test. The structure was designed to allow a change in the angle of the knee joint when other angles were tested. The maximum force value (Fmax) was obtained from the derivation of the signal using the Globus Ergo Tesys System 1000 software, registered by stretching the probe of the dynamometer.

The basic descriptive parameters were measured for all the variables, while stepwise multiple regression was used to obtain the regression model as a predictor of 1RM, with statistical significance set at $p<0.05$. The SPSS *(IBM SPSS Statistics 20. Chicago, IL, USA)* application program was used for mathematical processing of the original data, as well as their graphic illustration.

RESULTS

Table 1 shows the basic descriptive indicators of anthropometric variables. Considering the fat-to-muscle ratio (BMI) of the group, which is 4,14, it can be concluded that the examinees share a sport-specific morphology profile (Ugarković 1996).

Table 1. *Basic descriptive indicators of anthropometric and motor characteristics.*

Variable	N	Min.	Max.	AM	SD	CV
Height (cm)	24	168,00	190,30	179,63	5,96	0,03
Weight (kg)	24	57,10	95,00	73,89	8,85	0,11
Adipose tissue (%)	24	5,40	21,40	13,28	3,74	0,28
Muscle tissue (%)	24	45,30	52,40	49,69	1,67	0,03
BMI index(%)	24	2,22	9,25	4,14	1,63	0,39
Squat 80°	24	954	1957	1290,46	303,56	0,23
Squat 110°	24	1217	2714	1834,71	435,89	0,23
Squat 140°	24	1690	3198	2402,71	484,44	0,20
Aquat 1RM	24	115	191	150,41	21,56	0,20

Legend. **N** – the number of examinees, **Min**. – range minimum, **Max**. – range maximum, **AM** – arithmetic mean, **SD** – standard deviation, **CV** – the coefficient of variation

Table 1 shows that the highest average muscle force was achieved in the knee joint angle of 140 °, 2402 ± 484 N, then at an angle of 110 ° 1834 ± 435 N, and the lowest value was recorded at an angle of 80 ° 1290 ± 303 N.

Table 2 and Image 1 show that one model of multiple regression was singled out, which takes into account only the influence of the subtest **Squat 140** ° and tells us that the explanation of the criteria by the predictor R2 = 0.836, or 83.6%. Thus, the value of the isometric force achieved in the squat movement task at an angle in the knee joint of 140 ° is a good predictor (explanation of the criterion by the predictor 83.6%) compared to the values of the force achieved at one maximum effort in the squat movement task under dynamic conditions. The

standard measurement deviation was 9.1 kg, which is understandable due to the sample of respondents.

Table 2. *Regression model to predict 1RM on the basis of maximum isometric muscle force exerted in the leg press movement when at an angle in the knee joint of 140 °.*

MODEL 1		**SQUAT=a+b*SQUAT 140°**						
Equation parameters	Parameter value	Standard error	T(20)	P-level	R	R^2	Korig. R^2	St
a	**52,179**	9,196	5,674	0,000				
b	**0,0409**	0,004	10,889	0,000	0,918	0,843	0,836	8,72

Legend. **MODEL 1** predictor: Squat at 140º, Criteria: Squat

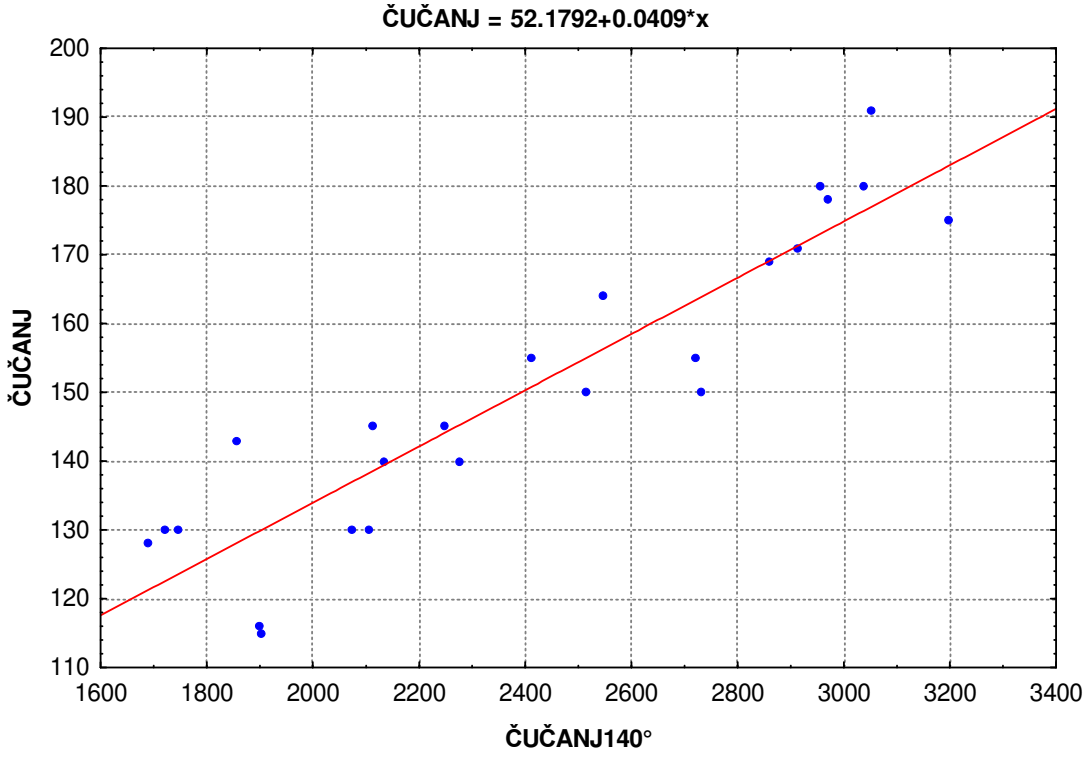

Image 1. *Prediction of 1RM based on the isometric force achieved in the squat test at an angle in the knee joint of 140º.*

Based on the analysis of the regression model, a unique formula for estimating one maximum repetition in the squat test 1RM = (52.1792 + 0.0409 * max isometric force at an angle of 140 °) with a reliability of 83.6% was selected.

DISCUSSION

The results of this study confirmed earlier findings (Smidtbleicher, 1992, Zaciorski and Kreamer 2009, June, 2010; Bazyler et al. 2015; Marchetti et al. 2016; Petrović et al. 2019) that muscle strength achieved in slow movements did not differ significantly from the maximum muscle force achieved under isometric conditions. Taking these findings into account it is important to emphasize that they refer to biomechanically similar movement patterns. The analysis of the results showed that body position, as well as a suitable angle in the knee joint, are very important when testing myogenic properties, which is confirmed by some previous research (Blazevich et al., 2002; Nuzzo et al., 2008; Demura et al., 2010; Caleb et al. 2015). The results of the study (Marchetti et al. 2016) on a sample of 50 well-trained individuals showed that the greatest force develops at an angle of 90 ° at the knee joint compared to angles of 40 ° and 160 °. According to research data (Bazyler et al. 2015), the highest correlation between 1 RM and the maximum muscle force of isometric squatting is at angles of 90 ° and 120 °. In the study with the students, the correlation of r = 0.77 was confirmed between 1 RM in the squat and Fmax at a joint angle of 90 ° in the isometric squat. These claims show that there is a result deviation obtained in this research compared to the previous studies. It should also be noted that the extent of the manifestation of strength and power depends on the training load program, time, and goals of the program. The respondents in this research paper were students who perform more exercises with larger joint angles in their training programs, which is one of the reasons why they exerted greater force at larger angles. The standard deviation of 9.1 kg can be attributed to the sample of subjects and, on the other hand, to the anthropometric characteristics. Thus, the patterns derived from this study relate to the sample of respondents used in this study. The patterns derived from this study relate to the sample of respondents used in this study.

CONCLUSION

The results obtained in this study show that from a methodological point of view, this approach to the study of myogenic properties is acceptable and that its principles can be used in future research. In order for the values of isometric force to be used as predictors for field tests, it is necessary to perform the test at a precisely defined body position, taking into account the angle in the joint at which the test is performed. Additional research should be conducted with professional athletes experienced in working with external loads by using more sophisticated equipment in the assessment of 1 RM in dynamic and isometric conditions. Kinematic parameters obtained using an isoinertial encoder and a tensiometric platform would reduce the measurement error.

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MAXIMUM ISOMETRIC MUSCLE STRENGTH AS A PREDICTOR OF ONE REPETITION MAXIMUM IN THE SQUAT TEST

SAŽETAK

Cilj ovog istraživanja je bio da se utvrdi da li ispoljavanje maksimalne izometrijske mišićne sile pri određenom uglu u zglobu koljena (80°, 110° i 140°) može služiti kao prediktor 1 RM-a kod kretnog zadatka čučanj (squat). Istraživanje je sprovedeno na grupi od dvadeset i četiri studenta (N=24), muškog pola u okviru 2 odvojene sesije sa po 7 dana odmora između svake. Antropometrijska mjerenja i procjena mišićne sile, odnosno 1 RM-a izvršeno je metodom repetitivnih maksimuma do otkaza na Smit mašini u okviru prve sesije. Maksimalna izometrijska sila (Fmax) muskulature nogu mjerena je testom uzastopnih maksimalnih kontrakcija u laboratorijskim uslovima na smit mašini uz pomoć sonde dinamometra i softwerskog sistema Globus Ergo Tesys System 1000. Analizom rezultata dobijenih na osnovu linearne regresije, autori zaključuju da sa preciznošću od 84,5% možemo izvršiti procjenu 1RM-a u vježbi čučanj na osnovu maksimalne izometrijske sila ispoljene pri uglu u zglobu koljena od 140°**.** Rezutati dobijeni ovim isztraživanjem mogu poslužiti aplikativno u praksi prilikom procjene 1 RM-a na osnovu mjerenja maksimalne izometrijske sile za dati kretni zadatak.

Ključne riječi: *Miši ćna sila, predikcija, 1 RM, čučanj*

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