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CONTENTS

Nikola Aksović, Bojan Bjelica, Marko Joksimović, Iryna Skrypchenko, Siniša Filipović, Filip Milanović, Bojan Pavlović, Bojan Ćorluka, Radomir Pržulj. Effects of aerobic physical activity to cardio-respiratory fitness of the elderly population: systematic overview	208
Nuri M. Çelik, Mehmet Soyal. The effect of exercise on homocysteine and some blood parameters in middle-aged sedentary individuals.....	219
Halil İ. Ceylan, Ahmet R. Günay. Positional differences in anticipation timing, reaction time and dynamic balance of American football players.....	227
Stefan Kolimechkov, Jose Castro-Piñero, Lubomir Petrov, Albena Alexandrova. The effect of elbow position on the handgrip strength test in children: validity and reliability of TKK 5101 and DynX dynamometers	240
Olga V. Limanskaya, Irina V. Kriventsova, Leonid V. Podrigalo, Olena V. Yefimova, Marina Jagiello. The influence of professional training disciplines on the physical fitness level of the folk dance department students	248
Ratko Pavlović. Differences in kinematic parameters between male and female hammer throw finalists of the World Championship in Daegu in 2011.....	255
Lachezar G. Stefanov, Ivan Ivanov, Daniela Aleksieva. Bilateral asymmetry of pedaling force at different levels of exercise intensity in cycle ergometer	264
Hüseyin Ö. Yurdakul, Barış Baydemir. Comparison of physical activity and skinfold thickness of students living in rural and city center.....	271
Information.....	278

Effects of aerobic physical activity to cardio-respiratory fitness of the elderly population: systematic overview

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Abstract

Purpose: Aerobic training is effective manner of exercising aimed at improving cardio-respiratory fitness of young people. However, its effects to the elderly population (over the age of 60), depending on characteristics of the participant (gender, health status, lifestyle, etc.), is still unclear. Aim of this research is systematic overview of the available literature dealing with the topic of effects of aerobic training to cardio-respiratory fitness of the elderly population over the age of 60, depending of gender (male/female), BMI (overweight/normal weight), lifestyle (active/sedentary), health status (diabetes/hypertension/metabolic syndrome).

Material: Total number of papers with published research results which met the criteria was 32. Walking is effective manner of exercising which influences improvement of maximum oxygen consumption (mean value: $\pm$ SD:12.91 $\pm$ 7.40%). Introduction of activities with greater impact (bicycle and jogging) provides more effect to the cardio-respiratory fitness (mean value: $\pm$ SD:14.28 $\pm$ 7.48%).

Results: Aerobic training intensity level (moderate vs. high) makes no significant difference to the adaptive response of the cardio-respiratory fitness in elderly population. Training in duration of 6 weeks may significantly influence increase in maximum oxygen consumption, but longer training duration, however, has better effect. Endurance training has similar effects to improvement of cardio-respiratory fitness in both men and women. On the other hand, it seems that active people have lower adaptive response in comparison to sedentary people (8.3% vs. 18.84%). Effect is similar between overweight and normal weight participants (18.48% vs. 8.6%). Positive influence of aerobic training was also observed in participants with hypertension, metabolic system and diabetes type 2.

Conclusions: Results clearly suggest benefits of aerobic training on cardio-respiratory fitness of elderly population. The effect may, however, vary depending of duration, type of activity, as well as characteristics of the sample.

Keywords: training, sedentary, VO₂max, walking, health, HRmax.

Introduction

Epidemiological studies indicate tight connection between exercising, health and fitness and the role of lifestyle to health of general population [1, 2]. Term *physical fitness* is related to certain level of being in physical shape. Additionally, it is used as synonym to certain types of exercising. Important fitness component linked to health status is cardio-respiratory fitness [3]. Cardio-respiratory fitness is the ability of cardio-vascular system and respiratory system to maintain oxygen supply to engaged muscles in duration of prolonged physical activity, as well as the ability of muscles to provide required energy in aerobic processes [4]. Maximum oxygen consumption (VO_{2max}) is the best indicator of aerobic capabilities of the organism and functional ability of cardio-vascular system, respiratory system and

tissue to use the available oxygen [5], which all reduces with aging. After the age of 25–30 sedentary people experience reduction of VO_{2max} 8–15% per decade [6]. Reduced capability to perform everyday activities after the age of 60 is caused by gradual reduction of VO_{2max} [8]. Aerobic training or endurance training is recommended for improving cardio-respiratory fitness and health benefits of elderly population. It may be defined as activity in minimal duration of 20 minutes where values of heart rate frequency are 60–80% of maximum heart rate frequency (HR_{max}) [9]. Previously performed meta-analyses confirmed the positive effect of training to VO_{2max} in elderly population. Despite important results obtained [10, 11] value of moderator in meta-regression analysis took value of 50 for independent variable *age*. Value for elderly people was (>50), which is an indicator of high variability among the participants. In the aforementioned study was also used common statistical method for calculation of the magnitude of effect of

various types of training (aerobic training, training with the load, etc.) to cardio-respiratory fitness. Second meta-analysis [10] included papers published in the period 1980–2002 and due to lack of available data, meta-regression analysis was not performed for the following variables: gender (male/female), BMI (overweight/normal weight), lifestyle (active/sedentary), health status. Up to date, the number of conducted research on the topic of effects of aerobic training to elderly population is low and requires information update. More sophisticated tools for assessment of performances and improved quality of research have also been developed. Therefore, aim of research is systematic overview of the available literature linked to effects of aerobic training to cardio-respiratory fitness of elderly population over the age of 60, depending of gender (male/female), BMI (overweight/normal weight), lifestyle (active/sedentary), health status (diabetes/hypertension/metabolic syndrome).

Material and methods

Data sources and search strategy

For the purpose of searching the available literature, following data bases were used: PubMed, MEDLINE, Google Scholar, ScienceDirect, ERIC from 1986 to August 2016. Searching was performed using following terms (individually or in combination): *physical activity, cardio-respiratory fitness, older adults, aerobic training, VO_{2max} effects, endurance training, walking, running, elderly*. Searching strategy was modified for each electronic database, where it was possible, with the aim of increasing sensitivity. All the papers and abstracts were evaluated for selection of potential papers to be included in the systematic overview. Lists of references and original research were also included in the analysis. One author performed literature search (EC). Relevant studies were obtained after detailed search if they met the criteria. The criteria are described in the following section.

Inclusion criteria

Type of study

Controlled randomised and non-randomised studies about effects of aerobic training to cardio-respiratory fitness in English language were included in the analysis.

Sample

Included participants are men and women aged over 60 regardless of lifestyle (active/sedentary), BMI (overweight/normal weight), health status (diabetes, metabolic syndrome, hypertension).

Type of intervention

Research establishing the effect of aerobic training.

Type of output results

Studies were included if the results present influence of aerobic training to VO_{2max} before and after aerobic training.

Exclusion criteria

Exclusion criteria were: 1) studies in languages other than English; 2) Age of participants under 60; 3) combination of aerobic training with training under load.

Data acquisition

Formatedusedfor dataacquisitionwasPICO(Participants,

Intervention, Comparison or control group, Outcomes) [12]: participants (and their health status, gender, BMI, lifestyle age), sample size, comparison of groups, training program (frequency, duration, type of activity, intensity) and acquired results (absolute and relative VO_{2max}). Data extraction was performed using Cochrane Consumers and Communication Review Group's data extraction protocol. Selection and assessment of data was performed by single author in order to maintain precision and to be comprehensive. All the selected papers were assessed in detail to collect required data. Authors of included papers were not contacted for missing data.

Results

In search results there were 785 identified potentially relevant studies, and 15 more after covering the references. After removal of double papers and abstracts there were 88 papers remaining. Upon completion of assessment of whole texts only 32 papers remained where all the criteria were met (Fig 1).

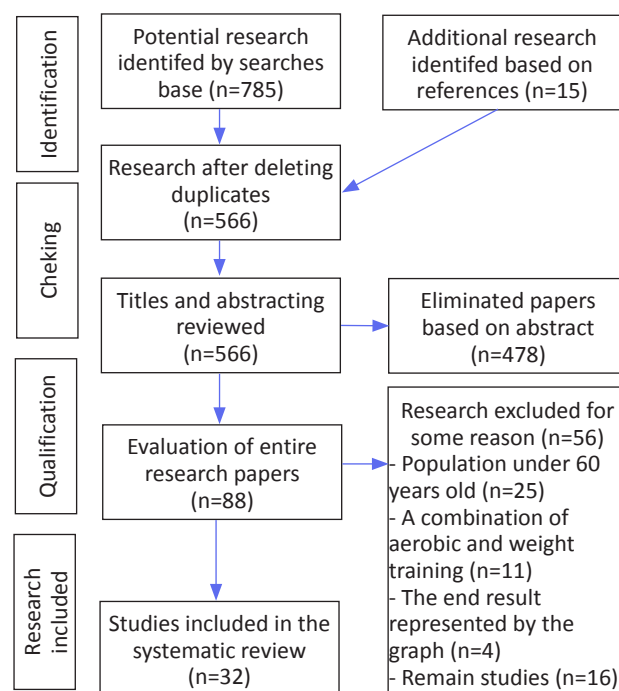


Figure 1. Flow Diagram

Aerobic training

Aerobic physical training triggers positive adaptive response to absolute and relative VO_{2max} . It seems that the simplest and most acceptable form of aerobic training is walking. Choice of this type of physical activity can be prescribed to less chance of injury, no supervision required and universal availability, which is why majority of authors researched influence of aerobic training in this training regime [13, 16, 20, 23]. Results of this systematic overview suggest that walking significantly improves absolute VO_{2max} values. Average improvement is $12.91 \pm 7.40\%$ (range 1%–27 %). Additionally, results of previous meta-analysis confirmed significant effect of walking to cardio-respiratory fitness in healthy sedentary population [25]. Contemporary studies [26, 27, 30,

Table 1. Systematic overview and characteristics of papers included in the research

Study		Population				Training program				Output results			
Health status	Gender	BMI (kg/m ²)	Lifestyle	Age	Sample size	Group comparison (n)	Frequency/ duration (days/ weeks)	Intensity	Training duration (min)	Type of activity	VO _{2max} (ml kg ⁻¹ min ⁻¹)	VO _{2max} (l min ⁻¹)	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
[26] Blumenthal et al. (1989)	healthy	♂/♀	/	/	67±4.9	101	EG (n= 33; M=17/F=16) KG1 (n=34; M=17/F=17) KG2 (n=34; M=16/F=18)	EG: 3/16 KG1: 2/16	70% HRmax	60	EG : bicycle, ergometer, walking, jogging KG1 : Yoga KG2: 2%↓	EG: 11.6 M=14.4%↑*; F=8.6%↑* KG1: 1%↓ KG2: 2%↓	
									EG1: 60% HRR EG2: 40% HRR	EG1: 45 EG2: 60	EG 1,2: Walking	EG1: 15%↑* EG2: 12.6%↑*	EG1: 21%↑* EG2: 12%↑*
[18]Foster et al. (1989)	healthy	♀	/	sedentary	EG1: 78.4±4.6 EG2: 78.4±6.4	16	EG1 (n=9) EG2 (n=7)	3/10					
[14]Belman and Gaesser (1991)	healthy	♂/♀	/	sedentary	65-75	27	EG1 (n=8; M=4/F=4) EG2 (n=9; M=5/F=4) KG (n=8; M=4/F=4)	4/8	EG1: 82% VO _{2max} EG2: 53% VO _{2max}	30	EG 1,2: Walking	EG1: 7%↑* EG2: 7.5%↑* KG: 2.3%↓	
												EG1: 11%↑* M=15%↑*; F=8%↑* EG2: 6%↑ M= 4%↑*; F=9.5%↑* EG3: 14%↑ M=16 %↑*; F=14.5 %↑*	
[27] Blumenthal et al. (1991)	healthy	♂/♀	/	sedentary	67 (60-83)	100	EG1 (n= 28) EG2 (n=31) EG3(n=31)	EG1: 3/32 EG2: 3/16 EG3:3/16	70% HRmax	60	EG1,2,3:Hand bicycle, ergometer, walking or jogging EG2: + yoga		
[22]Probart et al. (1991)	healthy	♀	EG:25.5±1.3 KG:23.3±1.1	sedentary	EG:72±0.6 KG:72±0.68	16	EG (n=10) KG (n=6)	3/26	70% HRmax	20	Walking	EG:8.4↑* KG:6.1↓*	EG:6.6↑* KG:5↓

Table 1 (continued).

1	2	3	4	5	6	7	8	9	10	11	12	13	14
[29]Kohrt et al. (1991)	healthy	♂/♀	/	sedentary	60-71	145	EG1 (n=41) EG1 (n=69) KG (n=35)	EG1: 4/52 EG2: 4/40	60-85% HRmax	30-50	EG 1,2: Walking and running, bicycle, ergometer	EG1: M=27.5%↑* F=20.5%↑* EG2: M=21.7%↑* F=22%↑* EG: M=2%↓ F=1%↓	EG1: M=22%↑* F=15%↑* EG2: M=15%↑* F=17%↑* EG: M=2%↓ F=1%↓
[35]Posner et al. (1992)	healthy	♂/♀	/	sedentary	68.6±5.1	247	EG (n=166) KG (n=81)	1/16	70% HRmax	40	Bicycle ergometer	EG: 8.5%↑* KG: 3↓	
[19]Nieman et al. (1993)	healthy	♀	/	sedentary	73.4±0.8	14	EG (n=14)	5/12	60% HRR	30-40	Walking	12.6%↑*	
[23]Warren et al. (1993)	healthy	♀	25.5±1.1	sedentary	73±0.7	16	EG (n=14)	5/12	60% HRmax	30-40	Walking	12.6↑*	
[15]Braith et al. (1994)	healthy	♂/♀	/	sedentary	EG1: 66±5 EG2: 65±4 KG: 66±5	44	EG1 (n=19) EG2 (n=14) KG (n=11)	3/26	EG1: 70% HRmax EG2: 80-85% HRmax	40	EG 1,2: Walking	EG1: 16%↑* EG2: 27%↑* KG: ~	
[33]Vitello et al. (1997)	healthy	♂/♀	/	/	M 66.9±1 F 67±1.3	52	EG (n=30; M=18/F=12) KG (n=22; M=13/F=9)	3/26	60-85% HRR	50-75	EG: walking, jogging, bicycle KG: flexibility	EG: 14.5%↑* KG: 1%↓	
[49]Vitello et al. (1996)	healthy	♂	/	/	69±1.3	15	EG (n=15)	5/26	60-85% HRR	50-75	Walking, jogging, bicycle	EG: 17.5↑*	

Table 1 (continued).

1	2	3	4	5	6	7	8	9	10	11	12	13	14
[17]De Vito et al. (1999)	healthy	♀	/	active	EG63.1±3.1 KG63.5±3.3	20	EG (n=11) KG (n=9)	3/12	60-70% HRmax	60	Walking	EG: 1%↑ KG:2.5%↑	
[24]Woods et al. (1999)	healthy	♂/♀	/	sedentary	65.3±0.8	29	EG (n=14) KG (n=15)	3/24	50-65% HRmax	40	EG:Walking KG:flexibility	EG:20%↑* KG:9%↑	EG:19%↑* KG:9%↑
[32]Turner et al. (2000)	hypertension	♂/♀	EG:30.2 KG:29.6	sedentary	EG65.2±1.4 KG68.5±1	18	EG (n=11; M=9/F=2) KG (n=7; M=5/F=2)	4/28	60-80% HRmax	40-60	Walking, jogging bicycle	EG:17%↑* KG:~	EG:16%↑* KG:~
[31]Pruchnic et al. (2004)	healthy	♂/♀	28±1	sedentary	67.3±0.3	13	EG (n=13; M=5/F=8)	3/12	50-70% VO _{2max}	30-40	Walking, jogging or stationary bicycle		12%↑*
[46]Broman, Quintana, Lindberg, Jansson, and Kaijser (2006)	healthy	♀	/	/	69±4	29	EG (n=18) KG (n=11)	2/8	75% HRmax	45	Walking, running in deep water	EG:11%↑* KG:3.6↑	EG:10.3%↑* KG:4.2%↑
[28]DiPietro et al. (2006)	healthy	♀	EG1 26.3±3 EG2 28±4.5 KG 27.7±4.7	sedentary	73±10	25	EG1 (n=9) EG2 (n=9) KG(n=7)	4/40	EG1: 80% VO _{2max} EG2: 65% VO _{2max}	60	EG1,2: Walking, jogging, bicycle or ergometer	EG1: 2%↓ EG2: 0.5%↓ KG: 2%↑	
[47]Coker, Williams, Kortebein, Sullivan, and Evans (2009)	healthy	♂/♀	EG1:30±1 EG2:28±1 KG:31±1	sedentary	71±1	18	EG1 (n= 6; M=3/F=3) EG2 (n=6; M=3/F=3) KG (n=6; M=3/F=3)	4-5/12	EG1: 75% VO _{2max} EG2: 50% VO _{2max}	30	EG1,2: Bicycle, ergometer	EG1:21%↑* EG2: 30%↑* KG: ~	

Table 1 (continued).

1	2	3	4	5	6	7	8	9	10	11	12	13	14
[30]Madden et al. (2009)	Diabetes type 2, hypertension, hypercholesterolemia	♂/♀	EG: 30.1±1.1 KG: 27.7±1	sedentary	71.4±0.7	36	EG (n=18) KG (n=18)	3/12	60-75% HRR	60	Bicycle, ergometer and treadmill	EG: 16.5%↑ KG: 4%↓	
[43]Yassine et al. (2009)	Metabolic syndrome	♂/♀	34.3±5.2	sedentary	65.5±5	24	EG1 (n=12) EG2 (n=12)	5/12	60-85% HRRmax	60	EG: Walking, bicycle EG2: EG1+ calorie restriction	EG1:15%↑* EG2:10%↑*	
[20]Ozaki et al. (2010)	healthy	♀	EG:22.5±0.9 KG: 23.2±1	sedentary	EG:64±1 KG:68±1	18	EG (n=10) KG (n=8)	4/10	45% HRR~70% VO _{2max}	20	Walking	EG: 9.7%↑* KG: 10.9%↑* KG:10.2%↑*	
[13]Atcharaporn et al. (2011)	healthy	♂/♀	25.1	sedentary	75±7	14	EG (n=14)	3/12	50-100% VO _{2max}	60	Walking	EG: 25%↑*	
[34]Niederseer et al. (2011)	healthy	♂/♀	EG:27.1±3.3 KG:25.4±2.8	active	EG66.6±2.1 KG67.3±4.4	42	EG (n= 27; M=14/F=13) KG (n=20; M=10/F=10)	2-3/12 /		207.5±14.1	Skiing	EG: 7%↑* KG:0.5%↓	
[44]Nuttamonwarakul, Amatyakul, and Suksom (2012)	Diabetes type 2	/	EG: 25.7±3.4 KG27.1±2.8	/	>60	40	EG (n=20) KG (n=20)	3/12	70% HRRmax	50	Exercises in water	EG:2%↑* KG:1%↓	
[37]Lovell et al. (2012)	healthy	♂	/	active	EG75.2±3 KG73.5±3.3	24	EG (n= 12) KG (n= 12)	3/16	50-70% VO _{2max}	30-45	Bicycle ergometer	EG:16.9%↑* KG: 1%↓	

Table 1 (continued).

1	2	3	4	5	6	7	8	9	10	11	12	13	14
[21]Predovan et al. (2012)	healthy	♂/♀	/	sedentary	67.96 ±6.25	50	EG (n= 25) KG (n= 25)	3/12	/	60	Fast walking, dance	EG: 24%↑* KG: 1%↑	
[39]Standley et al. (2013)	/	♀	/	/	70±2	9	EG (n=9)	3-4/9	60-80% HRR	20-45	Bicycle ergometer	EG: 30%↑*	
[45] Nuttamonwarakul, Amatyakul, and Suksom (2014)	Diabetes type 2	♀	/	/	60-70	19	EG1 (n=10) EG2 (n=9)	3/12	70% HRmax	50	EG1: exercises in water EG2: out of water	EG1: 1.7%↑* EG2: 2.6%↑	
[16]Chmelo et al. (2015)	hypertension	♂/♀	34.1±3.1	sedentary	69 ±3.6	40	EG (n=40)	4/20-21	65-70% HRR	30-40	Walking	EG: 7.9%↑*	
[36]Vigelsø et al. (2015)	healthy	♂	27±1	sedentary active	60-75	15	EG (n=15)	3-4/6	85%HRmax	48-58	Bicycle ergometer	EG: 10%↑*	
[48]Duffy (2016)	healthy	♂/♀	/	sedentary	60-80	247	EG1 (n=54) EG2 (n=54) EG3 (n=69) KG (n=70)	3/26	/	60	EG1: walking EG2 :walking + beta alanine EG3: dance KG: flexibility	EG1: 7%↑* EG2: 6.1%↑* EG3: 0.5%↑ KG: 1.5%↑	

Legend: ♂--male; ♀-female; /-no data; ↑- significant p< .05; ↑*-significant p< .01; ↓- significant p>.05; n--number of participants; EG-experimental group; KG-control group; HRR-heart rate reserve; HRmax- maximum heart rate; VO2max- maximum oxygen consumption.

31] also suggest that aerobic training may have more benefits to VO_{2max} when complemented with high impact activities such as jogging and bicycle ergometer (mean value $\pm$ standard deviation $14.28 \pm 7.48\%$). Skiing is yet another form of physical activity which reduces possibility of developing cardio-vascular conditions [34], but it is recommended to more active people due to risk of injury. Belman, & Gaesser [14] and Foster, et al., [18] state that in elderly population there is no difference, or there is slight difference, in adaptation to endurance training with various intensities (moderate vs. high intensity). These findings are to great extent in line with previous meta-analysis [10]. Results indicate that 60% intensity of VO_{2max} is adequate stimulus for improving cardio-respiratory endurance of elderly population. In addition to that, this overview revealed that trainings at low frequency (once a week) have positive effect to aerobic endurance [35]. Also, endurance training in duration of 6 weeks may significantly influence the increase in VO_{2max} (10%) [36]. However, numerous research performed validated that long duration endurance training (>16 weeks) can have greater effect to cardio-respiratory system [15, 29, 37, 32].

Discussion

There are numerous morphological and physiological differences between men and women connected to cardio-respiratory fitness [38]. Women have lower blood volume, lower count of red blood cells, lower haemoglobin, which all leads to lower oxygen capacity and hence ability to increase arterial and vein differences in O_2 . Despite number of physiological differences, it seems that aerobic training contributes significant increase in VO_{2max} levels in both men and women [18, 37, 39, 36]. Women show similar level of adaptation to one stimulus as elderly men [26, 29]. Similar adaptive response (increase in VO_{2max}) to endurance training in men was prescribed to increase in maximum minute volume (2/3) and increase in arterial-vein oxygen difference (1/3). On the other hand, women expressed no central adaptation, but only peripheral, due to the fact that increase in VO_{2max} levels was caused by increase in arterial-vein O_2 difference [40], whereas the increase of arterial-vein O_2 difference was caused by capillarisation of skeletal muscles and activity of mitochondrial enzymes [41]. It seems that hormones may influence lack of increase of minute and stroke volume, because women in post-menopause develop no hypertrophy of left chamber [40]. Changes contributing reduction in VO_{2max} level are numerous. VO_{2max} is very sensitive to changes in individual's lifestyle (active/sedentary). Cardio-vascular system oxygen transport capacity reduces with reduction in physical activity [42], and it increases as response to endurance training [16, 39, 36]. Niederseer et al. [34] performed research on influence of skiing to cardio-respiratory system of healthy elderly participants. In the research they applied training program in duration of 12 weeks where daily activity lasted for 3.5 hours twice or three times a week. Upon completion of three months of training, experimental group had significant increase in absolute VO_{2max} 7%, whereas

no changes had been observed in the control group. Positive effect of aerobic exercising was also presented by Lovell, et al., [37]. Research authors stated that endurance training in duration of 16 weeks, with intensity 50–70 VO_{2max} , three times a week significantly increases relative VO_{2max} (16.9%). However, training programs of similar capacity with similar load intensity lead to no improvement whatsoever in VO_{2max} of elderly women [17]. Authors found that the reason behind failure to have cardio-vascular adaptation was due to insufficiently long maintaining of intensity of physical activity in duration of training. Studies dealing with the effect of aerobic training to healthy active people show different findings, possibly due to type of physical activity performed as well as maintaining the intensity of physical activity in duration of training. Average improvement rate for active elderly individuals was 8.3%. However, these results should be interpreted with caution due to relatively small number of studies performed. People with sedentary lifestyle showed better adaptation to endurance training (mean value of absolute VO_{2max} 14.84%), probably due to lower baseline fitness. In majority of research sample consisted of healthy participants (77%), whereas other research (23 %) had patients with diabetes, hypertension or metabolic syndrome (see Table 1). Number of healthy participants was 1337, versus 177 (1 research had no health status included in the parameters $n=9$). Despite small number of research dealing with effect of aerobic training to people with hypertension, similar positive effect to cardio-respiratory system to healthy individuals was observed [16, 30, 32]. The effect was also observed in patients with metabolic syndrome [43]. On the other hand, even though participants with diabetes type 2 showed statistically significant increase in VO_{2max} in response to aerobic training in water, this increase is lower than in case of healthy individuals (around 2% vs. 15%) [44, 45]. Factor which contributes reduction in VO_{2max} is higher weight, especially in form of fat tissue. It seems that the effect of aerobic training in overweight individuals ($BMI > 30$) is higher in comparison to individuals with normal weight (18.48 vs. 8.6% absolute VO_{2max}). Better adaptive response to aerobic training may also be prescribed to lower baseline fitness, as in case of inactive individuals. However, lower baseline fitness of overweight individuals is caused by higher fat mass.

Conclusion

In this systematic overview we have briefly discussed practical application of aerobic training to elderly people over the age of 60, with focus on achieved effect depending of characteristics in the sample. In that sense we have to take into consideration that participants in the used studies were overweight ($BMI > 30$), with hypertension, diabetes type 2, metabolic syndrome, with different lifestyles (active/sedentary) and gender. Despite all that, results suggest clear benefits of aerobic training to cardio-respiratory system. Certain discrepancies may however be prescribed to characteristics of the sample. American College of Sport Medicine drafted guidelines

for improving cardio-respiratory fitness. In line with the guidelines, training should be held three times a week in duration 30–40 minutes with minimum intensity 50% $\text{VO}_{2\text{max}}$ or 60% Hrmax . As it has already been observed, aerobic training of such intensity seems to be strong incentive for improvement of cardio-respiratory fitness in aging process. Available results suggest that training in duration of only 6 weeks may significantly influence increase in $\text{VO}_{2\text{max}}$ [36], but that trainings in longer duration (>16 weeks) contribute to even greater extent to the cardio-respiratory fitness [7, 18, 22, 33]. Certain limitations of the systematic overview should be stated here. There are limitations in the external validity because majority of studies included in the overview examined influence of aerobic training to healthy individuals, whereas smaller number of studies was performed on individuals with hypertension, diabetes or metabolic syndrome. Further research on effects of aerobic training to active elderly population is required. Hence,

limited number of researches conducted in required sample makes difficult drafting final conclusions. It should also be emphasized that average improvement of cardio-respiratory fitness depending on characteristics of participants was expressed using absolute oxygen consumption, due to variability among studies. Despite limitations linked with effects of aerobic training of individuals with different health status, lifestyle and gender, endurance training can be recommended as safe and effective form of exercising used for improvement of cardio-respiratory fitness of elderly population.

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Conflicts of Interest

The authors declare no conflict of interest.

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The effect of exercise on homocysteine and some blood parameters in middle-aged sedentary individuals

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

Abstract

Purpose: The objective of this study is to examine the effect of exercise on the blood levels of homocysteine, hemoglobin and hematocrit in middle-aged sedentary individuals.

Material: A total of 24 middle-aged (35-55 years) sedentary individuals (12 females and 12 males) living in Batman province voluntarily participated in this study. Body weight, body mass index, Homocysteine, Hemoglobin and Hematocrit blood levels were measured before and after a walking exercise scheduled for 6 weeks. Walking exercise was administered 4 days a week for the 6 weeks. Initially, the walking exercises started as 40 min and increased to 60 min towards the end of the program. In the exercises, walking tempo was kept higher than normal and in parallel to the overall health levels of the subjects. The data obtained were then analyzed through the SPSS 25.00 package program.

Results: It was determined that there were statistically significant differences in the pretest and posttest parameters of body weight, body mass index, and Homocysteine values. Additionally, it was determined that, after the 6-week exercise program applied to the female and male participants, there were statistically significant differences between the pretest and posttest parameters of body weight, body mass index, hematocrit, hemoglobin, and homocysteine blood levels.

Conclusions: As the conclusion, it was determined that, after the 6-week exercise program applied to a total of 24 participants (12 females and 12 males), there were statistically significant changes in the values of body weight, body mass index, hematocrit, hemoglobin, and homocysteine blood levels. It is suggested for further studies to apply nutrition programs and exercise protocols on young people regularly doing exercise and active athletes in different branches in order to contribute to sports science.

Keywords: sedentary, exercise, homocysteine, hematocrit, hemoglobin.

Introduction

As is now globally accepted by everyone, exercise is an important factor in preventing many diseases. It is of vital significance that individuals, especially in the middle and advanced age groups, eat balanced and healthy foods in accordance with the age, exercise regularly and turn it into a lifestyle. Although this prevents many diseases, it may also cause some blood parameters to change depending on the type of the exercise.

Homocysteine (HCY) is a substance comprising of methionine, which is an amino acid taken by our bodies through the nutrients [1].

Methionine is found in foods that are rich in protein such as meat, eggs, fish and grains that we consume in order to sustain our daily lives. Homocysteine blood levels elevate in the middle and advanced age groups depending on many factors such as age, lifestyle, inadequate-incorrect nutrition, vitamin deficiency (B6 B12 folate) or a lifestyle without exercise, which ultimately causes many diseases particularly vascular occlusion and stroke in our body.

Homocysteine (HCY) is an aminoacid containing sulfur obtained from the nutritional protein and is an intermediate product formed during methionine metabolism [2]. Elevated concentration of total HCY

is an independent risk factor for atherosclerosis [2-6], cardiovascular diseases, stroke, and other thrombotic events [7-10].

Other vital factors affecting homocysteine include smoking, coffee, alcohol consumption and physical activity. It is reported that smoking, vegetable consumption, alcohol and coffee consumption have a strong relationship with plasma total HCY [11]. It was also explained that aerobic exercise lowers HCY levels compared to anaerobic exercise or a sedentary life [8].

Regular physical exercise is known to reduce the risk of developing cardiovascular diseases. It is also reported that the intensity and duration of exercise have different effects on plasma HCY levels today [5, 7].

Exercise is now a must in the world concerning the health. When it comes to living a healthy life or being a healthy individual, the treatments and pursuits in medicine are of course in the first place, followed by exercise and sports activities.

Homocysteine Metabolism

Homocysteine is an aminoacid, which is formed during methionine metabolism and which contains sulfur. Homocysteine has several forms in human plasma. They are bound to proteins, about 70-80% of which is mainly to albumin, by disulfide bonds. The rest of the homocysteine is oxidized, merging with dimers (homocysteine) or

cysteine to form mixed disulfides. Homocysteine is free to exist in circulation in a very small proportion (1%). Today, there are many techniques that can collectively measure different forms of homocysteine in plasma. With these methods, the measurement results are given as total homocysteine (HCY) [12].

The normal rate of HCY in the healthy population has been reported in several studies between 5-15 $\mu\text{mol/L}$ in hunger. This ratio is influenced by many factors, including being innate and acquired [13, 14].

In cases where methionine is surplus or Cysteine synthesis is required, homocysteine undergoes the trans-sulfuration. Here homocysteine combines with serine (an amino acid found in protein nutrients) to irreversibly form cystathionine through the enzyme cystathionine β -synthase, which is dependent on vitamin B6. Cystathionine is then hydrolyzed to cysteine. This is converted into glutathione or metabolized to sulfate at an advanced stage, ultimately being excreted in the urine [15].

Causes of Change of Homocysteine in the Body; Genetic Disorders in Metabolism

Homocysteine levels change as a result of genetic errors in human metabolism and nutritional deficiencies in cofactors such as vitamin B12, vitamin B6 and folate, which are essential for HCY metabolism. Homocysteine level is an important cardiovascular risk factor, and this factor is being affected from other factors as well. Other factors affecting homocysteine are age, gender, smoking, coffee, alcohol consumption and physical activity [16].

Nutrition Disorders

Deficiency of vitamin cofactors (B12, B6 vitamins, folate) essential for homocysteine metabolism in the nutrition can cause hyperhomocysteinemia. Significantly elevated homocysteine concentrations were also observed in the dietary deficiency of the essential vitamin B12 cofactor and folate co-substrate [17]. There is a negative correlation among serum vitamin B12, folate, vitamin B6 concentrations and plasma homocysteine concentration in normal individuals [17]. It was suggested that approximately 2/3 of patients with hyperhomocysteinemia were accompanied by a deficiency in one or more of the B vitamins. Although the addition of these to food normalizes the high level of homocysteine, it is not known whether this prevents cardiovascular mortality and morbidity.

Other Causes

Some diseases affect homocysteine metabolism. Plasma homocysteine concentration may rise 4 times above average as the creatine level elevates in patients with chronic renal failure [18]. Although plasma homocysteine levels often decrease after dialysis, it is difficult to show whether the increase in these patients is due to impaired metabolism or decreased excretion. The acceleration of atherosclerosis in renal failure in the terminal period can be partially explained by elevated plasma homocysteine concentration. In several publications, the relationship between hyperhomocysteinemia and hypothyroid was demonstrated, arguing that it has a role in increasing the

frequency of vascular disease in patients [19]. Additionally, although it is known that the level of homocysteine varies by exercise, this change in homocysteine levels varies by the duration and intensity of exercise [20].

Long-lasting high-intensity exercises increase protein metabolism and alter blood concentrations of certain amino acids. The reduction of available methionine also increases the synthesis of novo methionine, decreasing the accumulation of HCY. If there is enough folate, vitamin B6, and vitamin B12 in the protein turnover mechanism, HCY concentrations decrease during high-intensity long-lasting exercises. Contrary to this reaction, glycogen reserves are reduced by long-lasting exercises, which increases the necessity of vitamin B6-induced reactions. This results in an increase in the concentration of HCY with increased protein turnover during long-lasting exercise [21].

The fact that homocysteine levels are outside the normal limits will have many negative effects on our health. Knowing our homocysteine level, and if it is not within the normal limits, taking measures such as nutrition and exercise to balance this situation will protect us against homocysteine-related diseases. Some of these are serious diseases such as stroke and Alzheimer's, which are frequent in our age.

High concentration levels of homocysteine occur as a result of genetic errors in HCY metabolism and nutritional deficiencies in cofactors such as vitamin B12, vitamin B6 and folate, which are fundamental for HCY metabolism, and as a result of a lifestyle without exercise. Homocysteine levels are an important risk factor for cardiovascular diseases.

Previous studies demonstrated that regular physical exercise reduces the risk of cardiovascular diseases. However, when we examined the studies investigating the effects of physical activity on HCY [7, 8, 20, 22-24], it was also observed that the type, intensity and duration of exercise have different effects on HCY.

Hemoglobin is a compound found in red blood cells that transports oxygen from the lungs to skeletal muscles. Increased blood volume means that hemoglobin, which carries O_2 to the metabolism, carries more oxygen to the body. Therefore, the volume of hemoglobin and blood is directly related to the amount of oxygen carried, and therefore, it also determines the volume of the aerobic or oxygen system. In an intensive and heavy exercise, the transport of oxygen to skeletal muscle cells significantly increases [25].

Hematocrit (HCT) part of the blood is generally increased as a result of long-term aerobic exercises. The reason for this is a small reduction in the serum portion of the blood as a result of increased fluid loss during exercise. Blood parameters affect the type and intensity of exercise, similarly, exercise affects the blood parameters and it is important concerning various blood pathologies [26].

During and after an intensive exercise, there may be changes in hematologic values due to differences such as training level of the individual, gender, age, environmental conditions and nutrition. Hematological changes are

observed in athletes due to long-lasting exercises.

In athletes, who practice intensive exercise programs, the HGB and HCT values characteristically decrease, which is also described as athlete anemia [27, 28]. This is usually the case for measurements taken immediately after training.

There are many studies on how exercise affects hematological parameters. In fact, blood parameters affect the type and intensity of exercise, similarly exercise influences the blood parameters and it is important concerning various blood pathologies [29].

In the light of all this information, the aim of this study was to examine the changes in the blood levels of HCY, HCT and HGB during a 6-week regular exercise in the middle-aged group.

Material and Methods

Participants.

A total of 24 sedentary volunteers participated in the study, including 12 women with an average age of $43.58 \pm .94$ years and 12 men with an average age of 46.08 ± 6.82 years. The average height of women was measured as 162 ± 4 cm and that of men was measured as 175 ± 4.75 cm. All participants were informed about the exercises and they were asked to sign an informed consent form before participating in the exercises.

Research Design.

Certain features of the participant individuals such as body weight, height, and BMI (Tanita, Body Composition Analyzer, SC-240 Tokyo Japan) were measured before the exercise program and blood samples were taken. Blood samples taken by a specialist nurse before and after

the study program were analyzed in the Biochemistry Laboratory of Batman Regional State Hospital.

Exercise Protocol.

Participants were asked not to do any activity above normal level or take any medication prior to the tests. The exercise program was scheduled to last 6 weeks. Walking exercise was administered 4 days a week for the 6 weeks. Initially, the walking exercises started as 40 min and increased to 60 min towards the end of the program. In the exercises, walking tempo was kept higher than normal and in parallel to the overall health levels of the subjects. During the study, the subjects were not given a nutritional program.

Statistical Analysis.

The data obtained in the study were given as mean and standard deviation. Independent t test was used for inter-group comparisons and Paired t test was used for comparison of intra-group pretests and posttests, and the significance level was accepted as $p < 0.05$. SPSS 25 package program was used in the statistical analysis of the study.

Results

According to Table 1, the average age of the female participants was $43.58 \pm .94$ years and that of the male participants was 46.08 ± 6.82 years, while the mean height value of the women was 162 ± 4 cm and that of men was 175 ± 4.75 cm.

According to Table 2, the pretests of males and females were compared and it was determined that there were statistically significant differences concerning the Body weight, Body mass index, and homocysteine

Table 1. Demographical information of the participants

Variables	Gender	N	X $\pm$ SD	min	max
Age	Female	12	43.58 ± 5.94	35	53
	Male	12	46.08 ± 6.82	35	55
Height	Female	12	162 ± 4	156	170
	Male	12	175 ± 4.75	169	183

Table 2. Comparison of the inter-group pretest values

Variables	Groups	n	X $\pm$ SD	t	p
Body weight	Male	12	91.08 ± 5.55	13.072	0.01*
	Female	12	67.66 ± 2.77		
Body mass index	Male	12	29.52 ± 1.55	6.647	0.41*
	Female	12	25.70 ± 1.24		
Homocysteine (HCY)	Male	12	32.59 ± 4.41	5.735	0.02*
	Female	12	24.57 ± 1.97		
Hematocrit (HCT)	Male	12	43.54 ± 2.55	2.019	.056
	Female	12	41.34 ± 2.78		
Hemoglobin (HGB)	Male	12	13.51 ± 1.08	1.106	.281
	Female	12	$13.14 \pm .45$		

* $p < 0.05$

(HCY) parameters ($p<0.05$), while there was statistically no significant difference in the other parameters ($p>0.05$).

According to Table 3, the posttests of males and females were compared and it was determined that there were statistically significant differences concerning the Body weight, Body mass index, and homocysteine (HCY) parameters ($p<0.05$), while there was statistically no significant difference in other parameters ($p>0.05$).

According to Table 4, the pretest and posttest values of male participants were compared and it was determined that there were statistically significant differences concerning the Body weight, Body mass index, Homocysteine and Hemoglobin parameters at $p<0.05$ level, while there was statistically significant difference in the Homocysteine parameter at $p>0.05$ level.

According to Table 5, the pretest and posttest values of female participants were compared and it was determined that there were statistically significant differences concerning the Body weight, Body mass index, Homocysteine and Hemoglobin parameters at $p<0.05$ level, while there was statistically significant difference in the Homocysteine parameter at $p>0.05$ level.

Discussion

In this study, changes in the blood levels of Homocysteine (HCY), Hemoglobin (HGB) and Hematocrit (HCT) were examined before and after a certain exercise program in middle-aged (35-55 years) sedentary individuals.

In the previous studies of the literature, a comparison was made between middle-aged individuals, who were doing exercise, and sedentary individuals, concluding that the HCY levels were lower in exercise-doing individuals compared to sedentary individuals [7].

In another study, 82 individuals were classified in 4 groups as sedentary, aerobic, anaerobic, and intermittent exercise groups. It was determined that the aerobic exercise group, where there was a high energy consumption, had lower HCY levels compared to sedentary and intermittent groups. A decrease was detected in the total HCY levels with aerobic exercise [30].

In a different study, it was determined that there were significant reductions in HCY levels in obese women after a 6-month walking program. In this study, we see that chronic aerobic exercise programs reduce the HCY

Table 3. Comparison of inter-group posttest values

Variables	Groups	n	X $\pm$ SD	t	p
Body weight	Male	12	87.33 $\pm$ 3.89	15.530	.000**
	Female	12	65.25 $\pm$ 3.01		
Body mass index	Male	12	28.33 $\pm$ 1.68	5.690	.000**
	Female	12	24.78 $\pm$ 1.35		
Homocysteine (HCY)	Male	12	29.67 $\pm$ 4.85	4.979	.000**
	Female	12	22.29 $\pm$ 1.68		
Hematocrit (HCT)	Male	12	41.90 $\pm$ 2.08	1.666	.110
	Female	12	40.20 $\pm$ 2.85		
Hemoglobin (HGB)	Male	12	14.66 $\pm$ 1.05	1.075	.294
	Female	12	14.30 $\pm$.52		

** $p<0.001$

Table 4. Comparison of the pretest posttest values of the male participants

Variables	Groups	n	X $\pm$ SD	t	p
Body weight	Male	12	91.08 $\pm$ 5.55	3.469	.005*
	Female	12	87.33 $\pm$ 3.89		
Body mass index	Male	12	29.52 $\pm$ 1.55	3.575	.004*
	Female	12	28.33 $\pm$ 1.68		
Homocysteine (HCY)	Male	12	32.59 $\pm$ 4.41	7.380	.000**
	Female	12	29.67 $\pm$ 4.85		
Hematocrit (HCT)	Male	12	43.54 $\pm$ 2.55	3.320	.007*
	Female	12	41.90 $\pm$ 2.08		
Hemoglobin (HGB)	Male	12	13.51 $\pm$ 1.08	-3.372	.006*
	Female	12	14.66 $\pm$ 1.05		

* $p<0.05$ ** $p<0.001$

Table 5. Comparison of the pretest posttest values of the female participants

Variables	Groups	n	X±SD	t	p
Body weight	Male	12	67.66±2.77	3.469	.005*
	Female	12	65.25±3.01		
Body mass index	Male	12	25.70±1.24	3.575	.004*
	Female	12	24.78±1.35		
Homocysteine (HCY)	Male	12	24.57±1.97	7.380	.000**
	Female	12	22.29±1.68		
Hematocrit (HCT)	Male	12	41.34±2.78	3.320	.007*
	Female	12	40.20±2.85		
Hemoglobin (HGB)	Male	12	13.14±.45	-3.372	.006*
	Female	12	14.30±.52		

*p<0.05 **p<0.001

blood levels [31].

In different research studies, women between the ages of 19-38 were divided into 3 groups and the first group was only administered creatine for 8 weeks, the second group was both applied resistance training and creatine, and the third group was given resistance training and placebo. Significant reductions were determined in plasma HCY levels in the second and third groups both of which underwent resistance training. In these two studies, it was observed that resistance exercises as well as aerobic exercises had positive effects on HCY [32].

In another study conducted by [20], it was found that total HCY levels were significantly lower in the physical activity group comprising of 118 middle-aged subjects. Furthermore, a significant inverse relationship was determined between plasma total HCY and aerobic physical capacity.

In a different research [33], it was stated that the 4-week exercise program in healthy men reduced the level of HCY, a different study [34] concluded that elevated plasma HCY levels in the increased risk of CVD in the elderly were partly related to lack of exercise.

Real et al. [22] determined a 19% elevation in post-race HCY levels of 26 professional and 26 amateur male athletes between the ages of 23-49. In another study [35], following a 6-month high intensity training, it was determined that there was an elevation in the post-training HCY levels of 327 healthy participants with an average age of 48.9.

In a study conducted on healthy triathletes between the ages of 19-34 [23], an increase was detected in the HCY values.

In another research [8], it was observed in endurance athletes that there were moderate hyperhomocysteinemia, vitamin B12 deficiency, and low folate levels. In a study conducted by [36], no change was detected in HCY levels in the group performing an 8-week aerobic training

with vitamin intake, while there was an increase, though not statistically significant, in HCY levels in the group performing the aerobic training with placebo intake.

In a different study [37], it was determined that there was no change in plasma HCY levels in 16 healthy sedentary male participants after a walking program 30 minutes each day at least 5 days a week for a total of 6 weeks.

Apart from long-term aerobic exercises [38], after a 6-month high and low intensity resistance trainings applied to 60-80 year-old healthy participants, it was determined that the serum HCY levels were lower than the control group following both resistance trainings.

In another study [24], the effects of acute exercise on plasma HCY levels were investigated on 20 physically active healthy men between the ages of 24-39. As a result of the study, it was determined that acute exercise did not affect plasma HCY levels in healthy men aged 24-39.

Moderate hyperhomocysteinemia can often occur among endurance athletes, accompanied by low levels of folate and vitamin B12. In a study conducted by [39], it was found that there was an increase in HCY levels in women after exercise in parallel to the menstrual cycle.

A different research [40] detected significant increases in hemoglobin values in subjects after an 8-week aerobic exercise. In a study conducted by [41], it was determined that there were significant increases in the hemoglobin levels of the subjects in an exercise program at 60-80% of max VO₂. A different research [42] found a significant increase in hemoglobin levels in sedentary individuals after chronic exercise. Another study [43] conducted on adults aged 18-29 classified as normal and supplementary food groups, it was found that there were significant increases in hemoglobin levels in both groups as a result of an 8-week aerobic exercise. A different study [44] examined the chronic effects of extensive interval training on male athletes, determining significant increases in

hemoglobin after an 8-week chronic exercise.

As a result of a study [45], in which 4 weeks of intensive training was applied after a 2-week normal training, it was determined that there were rhythmic and meaningless reductions in hemoglobin parameters at the first, second, and third weeks, while regular and significant increases were determined at the fourth, fifth, and sixth weeks.

In different previous studies, following an 8-week aerobic exercise [40], after 6 weeks of a moderate exercise on sedentary youth [46], and following acute exercise on men aged 32 years [47], the significant elevations were detected in HCT levels of the participants ($p < 0.05$). It was determined that there were significant increases in HCT values of 10 athletes following a 20-day chronic exercise [48].

In previous studies in the literature, it was determined that following a 20-day camp period for 25 athletes, no statistical changes were detected in HCT levels [49], a 6-week high interval training did not produce an increase in HCT levels [50], or at the end of the 5-week training program for 16 male and 8 female judo athletes it was determined that there was a reduction in hematocrit values [51] ($p < 0.05$).

In a study [52] conducted on 11 (7 males, 4 females) Olympic athletes, the blood samples of participants were taken after the season at high altitude, and it was found that, at high altitudes, there were significant increases in HGB, RBC, HCT, MCV parameters. There were statistically no significant changes in WBC, PLT, MCH and MCHC parameters. Similarly, no significant differences were recorded in any parameters in the post-season measurements. In another research [53] conducted on marathoners, it was determined that, following the race, there were increases in erythrocyte count, hemoglobin, hematocrit, MCH blood levels and decreases in MCV levels compared to pre-race figures. In addition, reductions were detected in the erythrocyte count, hemoglobin and

hematocrit levels after longer-term exercises such as the 20-day road race [54].

In another study, the subjects underwent a 2-hour running exercise that resulted in a 4% reduction in body weight, detecting a 12.2% reduction in plasma volume, a 6.3% reduction in erythrocytes, and a 9.6% reduction in blood volume. On the other hand, in some other studies no changes were determined in the volume of erythrocytes [55]. The ratio of hematocrit is around 42-50% in normal men, and around 37-47, 1 % in normal women [56].

In a different research, it was demonstrated that acute submaximal exercise significantly elevated erythrocyte, hematocrit (HCT), hemoglobin (HGB), leukocyte and platelet levels compared to pre-exercise values, concluding that these elevations are due to plasma losses caused by exercise. It was suggested that short-term exercise conducted until fatigue increases the number of leukocytes, and that this event cannot be explained only by the mechanism of hemoconcentration, and may also be related to metabolic changes that occur during the exercise [27].

Considering the studies in the literature, it is observed that the responses of blood values to exercise vary.

Conclusions

As a conclusion, examining homocysteine, hemoglobin, hematocrit and some other blood parameters of a total of 24 participants (12 men and 12 women), it was concluded that there were significant changes in HCY, HGB, HCT levels depending on the duration and intensity of the exercise. It is suggested for further studies to apply nutrition programs and exercise protocols on young people regularly doing exercise and active athletes in different branches in order to contribute to sports science.

Conflict of interests

The authors declare that there is no conflict of interests

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Positional differences in anticipation timing, reaction time and dynamic balance of American football players

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

Abstract

Purpose: The aim of this study was to compare the coinciding anticipation timing (CAT), reaction time and dynamic balance performances of American football players according to their playing positions.

Material: Thirty-five American football players, who train at least 3 days a week, and compete in Universities Protected Football 1st League, participated in this study, voluntarily. The players were divided into two playing positions: offensive (17 players, mean age: 20.76 ± 1.30 years) and defensive (18 players, mean age: 21.94 ± 2.87 years). The CAT at different stimulus speeds (6 mph, 12 mph), reaction time (visual, auditory, mixed), and dynamic balance performance (anterior-posterior, medial-lateral, perimeter length) were measured in the laboratory environment. The CAT, reaction time, and dynamic balance performance of players were determined by Bassin Anticipation Timer, Newtest 1000, and Technobody Prokin-200, respectively.

Results: The data obtained were analyzed in SPSS (20.0) program. Firstly, the raw data for CAT performance (6mph, 12 mph) were converted to absolute error score. According to Shapiro-Wilk test result, the all data showed normal distribution. Independent Sample t test was used to determine the differences between the two playing positions. In addition, the effect size between the two playing positions was calculated in parameters with showing significant differences, and Cohen's d (1988) values were taken into account. Compared with the defensive players (20.15 ± 3.81 ms), the absolute error scores at fast stimulus speeds (12 mph) of offensive players (17.45 ± 3.48 ms) was found to be significantly lower ($t_{(33)} = -2.181$, $p = .036$). The visual reaction time of offensive players (318.11 ± 17.47 ms) was significantly shorter than defensive players (340.58 ± 32.60 ms, $t_{(26322)} = -2.560$, $p = .017$). In terms of dynamic balance parameters such as perimeter length, anterior-posterior, and medial-lateral, there was no statistically significant difference between the playing positions ($p > 0.05$).

Conclusions: Perceptual-cognitive characteristics such as CAT, and reaction time performance differ according to the playing positions, and this difference may be related to the physical, and cognitive demands required by their playing positions.

Keywords: american football, coinciding anticipation timing, dynamic balance, reaction time.

Introduction

American football is one of the most competitive, and popular team sports in the United States [1]. The game is played at the college level in National Collegiate Athletic Association (NCAA), and at the professional level in the National Football League (NFL) [2]. The NFL is the highest athletic competition level for American football, and competing in NFL requires exceptional skills and physical abilities [1]. American football is a crash-based sport including intense physical collisions, and characterized by intermittent short duration maximum high intensity activities separated by short rest times between games. It requires physical performance characteristics such power, strength, speed, acceleration, deceleration [2-6], and also skills such as catching, throwing, backpedalling, stealing, blocking, backpedalling, and back-pedaling, and sudden multi-directional running in-match performance [7]. The game is played by 11 players on each team. The playing positions are grouped into defensive (defensive backs, DB; linebackers, LB; defensive linemen, DL),

offensive quarterbacks, QB; running backs, RB; offensive linemen, OL; wide receivers, WR; halfbacks, HB, and special (kickers, K; punters, P) players [8]. Each playing position has specific responsibilities, and the physical, physiological, biomechanical, and perceptual-cognitive demands of the game are quite different for players in different positions [3, 6, 8, 9]. American football is played in a chaotic visual environment filled with relevant, and distracting information that negatively affects the response potential of the players [10]. Therefore, the ability to quickly and accurately predict or perceive relevant information within a limited time in a unpredictable environment facilitates sudden, fast and accurate decision-making, gives the player more time to prepare, and regulate their motor behaviors [11, 12]. Performing such actions in complex game sequences that are not previously determined involves high-level perceptual-cognitive, and advanced sensorimotor characteristics [10, 13, 14]. These characteristics are CAT, reaction time, and balance performance.

According to Fleury & Bard [15], CAT is the capacity to predict the approach of a moving object in a particular

sign in space, and to synchronize the movement response with that arrival. In sports, because of the dynamic nature of the environment, and the fact that players need to display their activities in a limited time, CAT performance is very important, and forms the basis for high performance [16, 17, 18]. Elite athletes or players predict when and what will happen in the environment, and for this, they use various information processing activities before the stimulus [19]. They take all the necessary information from the postural, and kinematic cues resulting from the opponent's movement [16, 17, 20], pattern recognition [21], direction, and speed of the ball [22] in the prediction process. CAT performance is also very important in American Football, and two kinds of anticipation can be mentioned. These; spatial and temporal anticipation. Spatial anticipation, the player receives information from the opponent about the content of the movement, and when it will take place, and then react to the movements in a very short time by taking the correct position. He organizes the movements in advance. In American football, defensive lineman knows which game is being played, and starts his movement simultaneously according to the game. The interception of ball in the air can be an example of temporal anticipation. In this anticipation type, despite having a strong clue about when the event will occur, being unable to predict what will happen prevents the player from organizing his action in advance [19]. In addition, players face situations in American Football that prevent them from predicting or 'reading' the situation. Such situations force the player to react after the event (due to the oval shape of the ball, the ball may bounce randomly, the bounce direction of the ball can be difficult to predict) [16].

The reaction time is defined as the minimum time between taking a sudden, and unexpected stimulus, and the reaction given to it [23]. In American football, having a short reaction time of the player is a critical component in terms of responding to the stimuli as quickly and accurately as possible, by choosing the relevant ones from many information in the chaotic visual field, and provides an advantage in games [24, 25]. Mankowska et al. [26] observed that a player's ability to quickly assess an opponent's position and direction is significantly related to response times. The offensive players such as wide receivers, running backs, and quarterbacks can make athletic moves in the opposite direction to distract defenders and cause slow their reaction times. Therefore, the fast and accurate response time of the defensive players should be very good against certain hints on the field, and especially the surprising movements of the offensive players, and also minimizing their reaction time as much as possible to increase the chances of successfully 'winning' a game is crucial to preventing offense or scoring [25]. Likewise, the reaction times of offensive players also need to be very short in order to successfully make sudden changes, and maneuvers with rapid movement of the limbs in the games, and to gain points [27].

Dynamic balance is the ability of the individual

to maintain the stability of the center of mass during movements, and is important in American football as in many sports branches [28]. American football requires players to have unprecedented coordination, that is, dynamic balance ability, to deal with rapidly changing external conditions, complete complex multi-directional movements at high speed, and to succeed in blocking, catching, change of direction, and tackling under pressure or in contact with opposing players [29, 30]. Compared to other sports branches, injuries are very common in American football, and poor dynamic balance performance and increased swing are associated with a higher risk of injury. The NCAA reported that more than 3 million players suffered injuries as a result of the analysis of data from 3 NCAA leagues from 2004 to 2014 [31]. Due to the characteristic nature of the game, contact or collision with players is the primary cause of injuries, and injuries are mostly strains or sprains that affect the lower limbs [32, 33].

It was reported that each game lasts an average of 5.49 s (between 1.87 and 12.88 s) at the college level, and in NFL, each game takes an average of 5.0 s. [3]. This information shows that the game plays very fast, and ends in seconds. The players are exposed to collisions, and blunt force trauma as a result of frequent repeated contact with opponents, and the ground during tackling, blocking, and ball handling activities. This induces additional stress on players, which is not common in other forms of physical activity [34, 35]. Despite this stress, it is important that players have and maintain their high-level perceptual-cognitive functions, and advanced sensorimotor characteristics during the games to gain points, to advance the ball, to intercept injuries by preventing possible collisions with the opponents, to move quickly to empty spaces without colliding, and to throw the ball to their teammates at the right time by reading the game well. In the literature, there are some studies that evaluate the performance characteristics of American football players such as sprint and jump (9), match performance [35], running and non-running activities [2], impulse control [36], executing motor responses in the face of distraction [10], and impact profiles which they are exposed to [5] according to the their playing positions. There is limited study comparing the perceptual-cognitive, and sensorimotor characteristics of American football players such as CAT, reaction time, and dynamic balance performance by their playing positions. This reveals the importance of the study in terms of literature. In line with previous studies [37, 38], and considering the nature of American football, our first hypothesis was established that offensive players have better CAT, and reaction time performance than defensive players. The second hypothesis was that defensive players have superior dynamic balance performance than offensive players.

Material and Methods

Participants

Thirty-five volunteer American football players, who

do not have any health problems, train at least 3 days a week, and compete in Universities Protected Football 1st League, participated in this study. Before the study, face-to-face interviews were held with the players about the purpose, importance, content, and methodical model of this study. The volunteers were determined to participate in the study, and Informed Consent Form was signed, and then the players were divided into two the playing positions: offensive (17 players; quarter backs, running backs, offensive linemen, receivers, mean age: 21.94 ± 2.87 years), and defensive (18 players; defensive backs, line backers, defensive linemen, mean age: 20.76 ± 1.30 year)

Research Design.

Collection of Data

The measurements were carried out between 08.00-11.00 hours in Mugla Sitki, Kocman University Performance Laboratory. One day before the day of measurements, the players were informed about avoiding to perform exercise at high intensity, getting enough sleep (at least 10 hours), and not using substances such as alcohol, caffeine, and stimulants. On the measurement day, all players were present at the laboratory at 08:00 a.m. Firstly, the height and body weight of players were collected, and then their body fat percentage was calculated by Tanita. Then, the players were individually taken to a quiet, calm, and low-light environment, and their CAT performance were measured randomly at different stimulus speeds (6 mph and 12 mph). (Table 1). Visual (light), auditory (sound) and mixed (light or sound) reaction time measurements were performed after the CAT measurements in the same environment. After 15 minutes dynamic, and static warm-ups exercises [39], the dynamic balance performance of the players (anterior-posterior, medial-lateral) were determined using the Prokin 200 device.

Data Collection Tools

Height and body weight measurements: Th body weight of the players were determined by Seca (Germany) electronic scale with a sensitivity of 0.01 kg, and their height were measured in bare feet, and standing upright position with a metal meter with a precision of 0.01 cm, which is fixed in that scale [40].

Body fat percentage: Bioelectrical Impedance Analysis (Tanita TBF-401A device) method was utilized to detect the body fat percentage of the players. Before coming to the measurements, the players were informed about the criteria proposed by the American College of Sports Medicine [41] to minimize the error in the

measurements. The players were asked to step on the four contact electrons mounted on the platform surface with bare feet, stand motionless, and upright until the results appear on the screen. The body fat percentage was calculated automatically with special equations pre-programmed by the manufacturer [42, 43].

CAT performance: The Bassin Anticipation Timer (Lafayette Instrument Company, Model 35575) was used for CAT measurements at different stimulation speeds (6 mph and 12 mph) of players. This device was developed by Stanley Bassin to assess the visual acuity area associated with hand eye coordination, and anticipation. In the literature, it was reported that this device is a valid, and reliable method used in the evaluation of CAT performance in the studies performed in different sports branches [37, 44, 45, 46, 47]. Rodrigues et al. [48] stated that 6 mph (268 cm/s) stimulus speed as “slow”, and 12 mph (536.4 cm/s) warning speed as “fast”. Therefore, the criteria of Rodrigues et al. [48] were taken in choosing 6 mph, and 12 mph stimulus speeds in CAT performance measurements in this study. The device comprises three parts called a control console, a response button, and a runway (set; ground on which LED lights move, 2.24m) where LED lights act in a linear series (49 lamps, 1st lamp yellow colour = warning lamp). The sequentially lighted LED lamps illuminate in a linear pattern with movement occurring from right to left [49]. The device was placed on a table, approximately 87 cm above the floor. Before the measurements started, the start and end speeds were fixed at 6 mph and 12 mph, and the target light was determined as the 8th lamp of the 3 sets. The warning light was adjusted with a random delay of 1 (minumum) to 2 seconds (maximum) to reduce the chance of participants predicting the test time [50]. Then, the players were invited to a quiet, calm, and low-light environment one by one. Before the actual measurement, the players were allowed to familiarize with the Bassin Anticipation Timer, necessary explanations about measurement were reminded again, and each player was given 10 trials at each stimulus speeds. After the trial measurements were completed, the players waited ready at the beginning of the device, and the signal was sent by the researcher. The players were asked to press the button using the dominant hand as close as possible to the time of arrival of the stimulus at the target location (target light) [44, 49, 50]. A total of 20 randomized measurements (10 for 6 mph, and 10 for 12 mph) were taken from each player. In addition, in 20 randomly taken measurements, the same stimulus speeds sequence was applied for both positions (offensive,

Table 1. The CAT measurements at different stimulus speeds measured randomly according to playing positions

Offensive	12 mph	12 mph	6 mph	6 mph	6 mph	12 mph	12 mph	12 mph	6 mph	6 mph
	12 mph	12 mph	12 mph	6 mph	6 mph	6 mph	6 mph	6 mph	12 mph	12 mph
Defensive	12 mph	12 mph	6 mph	6 mph	6 mph	12 mph	12 mph	12 mph	6 mph	6 mph
	12 mph	12 mph	12 mph	6 mph	6 mph	6 mph	6 mph	6 mph	12 mph	12 mph

and defensive) to ensure the inter-position measurement standard. This same stimulus speeds sequence is shown in Table 1. The results were recorded in milliseconds according to whether the response was early or late. The raw scores from two different stimulus speeds (6 mph and 12 mph) were converted to absolute error scores. While performing CAT measurements, the players were not verbally instructed, and also were not informed about stimulus speeds order.

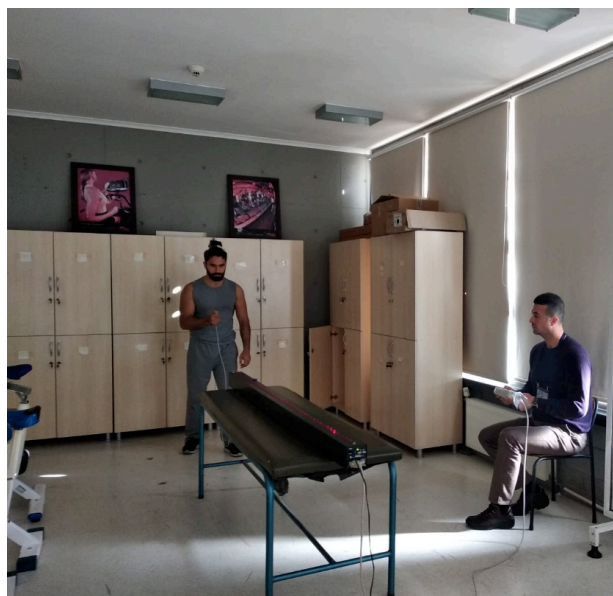


Figure 1. The CAT performance measurement

Absolute error score: It is a measure of timing error, which is frequently used in studies related to CAT performance. The absolute error gives information about the magnitude of the error made by the participant during the trial, and trial series. It also expresses the absolute value of each raw score obtained as a result of the measurement, regardless of whether the response is early or late, and explains the individual and combined effects of task characteristics as a whole. The score obtained shows the general accuracy index of an individual's performance. A high score indicates that more errors were made during the trial or trials [44, 47, 51].

Reaction time measurement: The visual (light), auditory (sound), and mixed (light or sound) reaction times of players were measured by The New Test 1000 device with a sensitivity of 0.01 s. The Newtest 1000 device gives three stimuli, and consists of two separate parts, such as the warning device, and the warning sign for the participant to receive the warning. While, buttons 1 and 3 in black on the device provide visual, and number 2, that is, red stimulus in the middle gives auditory (sound) stimulus. The stimuli are given by the practitioner in a way that the participants can not see. The device gives values over 1/1000 sec. During the application phase of this research, the players were taken to a quiet, calm, and low-light environment one by one, and the device was placed on the table 10 cm away from

the player. The players were asked to put their dominant hands on the table. Later, the researcher sent light, sound, sound or light stimuli, respectively, and players were desired to react to these stimuli as quickly as possible. Ten measurements were taken for each reaction time (visual, auditory, mixed), the highest and lowest values were not evaluated. The average of the remaining 6 measurements was used for statistical analysis [52].

Dynamic balance measurement: The dynamic balance performance of the players was designated with a portable movable balance platform Prokin Tecno Body (PKW 200 PL, Italy) with a measurement accuracy of 0.1°. This device is required for dynamic proprioceptive exercises (especially based on sports applications) for the lower extremities, and proprioceptive control of the trunk. The device has a small silicon chip that can detect every single angular movement with maximum accuracy. The platform has an excellent hemisphere that provides angular detection of multiple axes. The difficulty level can be changed as desired thanks to three interchangeable variable diameter discs in the system. (Easy-Medium-Hard). The system software wirelessly detects, and records every movement in real time, and provides the researcher with detailed data about the participants. Before starting the measurements, the degree of difficulty of the device was set to "medium" to measure the bi-directional dynamic balance ability. At the same time, the player was explained in detail how to perform the test. After entering the age, height, and body weight values of each player into the system, the device was calibrated. Then, player had one trial. In main measurements, the players were wanted to open their feet on the platform with their shoulders wide, and stand with their knees flexed slightly. After the foot coordinates were determined on the platform, and providing the balance on the platform, the test was initiated by the researcher in computer environment. The test was performed only once, with eyes open for each player, and consisted of trying to act in a reference circle defined by the researcher for 30 seconds. After the test was completed, three measurement values (perimeter length, medium equilibrium center-AP, medium equilibrium center-ML) were taken into account for statistical analysis. An increase in the perimeter length score indicates poor balance performance. The high AP and ML value indicates the weakness of quadriceps/hamstring muscles, and the lower leg muscles in neuromuscular control during inversion and eversion movement, respectively [53].

Statistical Analysis. The data was analyzed in SPSS (20.0) program. According to the Shapiro-Wilk test results, the data showed normal distribution. Independent Sample t test was used to compare the CAT (6 mph, 12 mph), reaction time (visual, auditory, mixed), and dynamic balance performances (perimeter length, anterior-posterior, medial-lateral) of American football players according to their playing positions. In cases where there was a significant difference, the effect size between the two groups was calculated. Cohen's d [54] values were taken into consideration for the effect size. Significance level was accepted as $p < 0.05$.

Results

Table 2. The age, height, body weight, body fat percentage and experience values of players

Variables	Playing Positions	N	M± S.D.
Age (years)	Offensive	17	20.76±1.30
	Defensive	18	21.94±2.87
Body Mass (kg)	Offensive	17	87.15±14.24
	Defensive	18	89.77±14.49
Height (m)	Offensive	17	1.77±.06
	Defensive	18	1.80±.03
Body Fat (%)	Offensive	17	17.04±6.20
	Defensive	18	16.52±4.71
Experience (years)	Offensive	17	2.05±.82
	Defensive	18	2.44±1.04

In Figure 2, absolute error scores for 6 mph is given in milliseconds. According to the boxplot chart; When absolute error scores (6mph) of offensive (20.35±8.42 ms), and defensive players (22.06± 7.14 ms) were compared, there was no statistically significant difference [$t_{(33)} = -.651$, $p = .520$, Levene's test = .854]

In Figure 3, absolute error scores for 12 mph is shown in milliseconds in the boxplot chart. As compared to defensive players (20.15±3.81 ms), absolute error scores (12 mph) of offensive players (17.45±3.48 ms) were found to be statistically significantly lower [$t_{(33)} = -2.181$, $p = .036$, Levene's test = .841]. This shows that the CAT performance of offensive players was better than defensive players at fast stimulus speeds (12 mph). Significant difference was marked with a star. The effect size for absolute error scores (12 mph) between offensive and defensive players were determined as 0.73. According to Cohen's d [54], the effect size was medium between two groups.

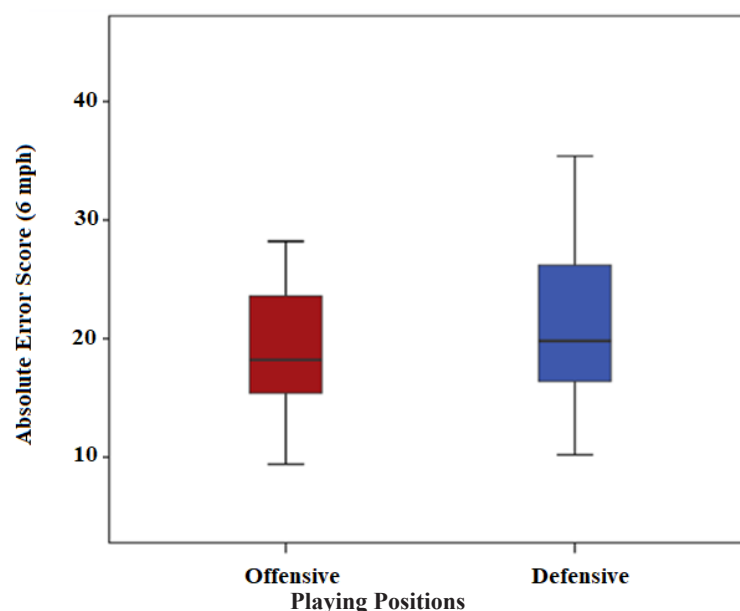


Figure 2. Comparison of Absolute Error Scores (6 mph) of American football players according to playing positions

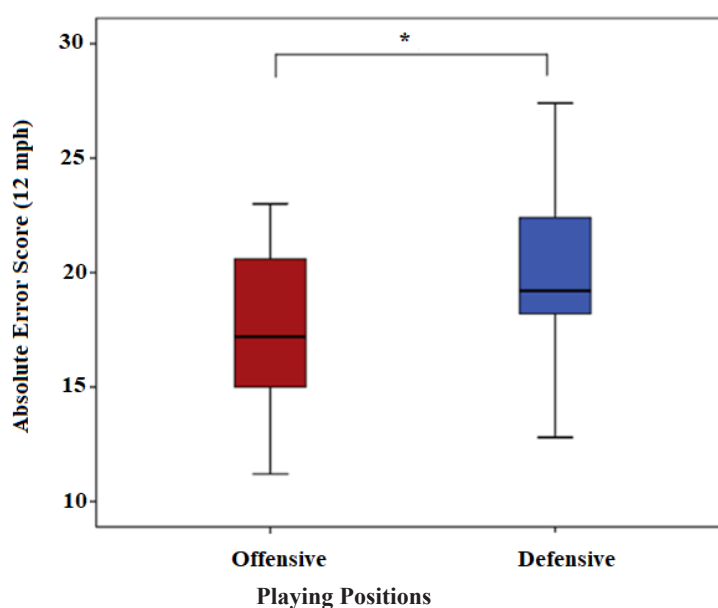


Figure 3. Comparison of Absolute Error Scores (12 mph) of players according to playing positions

In Figure 4, the visual reaction time performance was demonstrated in milliseconds in the boxplot chart. It was found that offensive players (318.11 ± 17.47 ms) had a significantly better visual reaction time than defensive players (340.58 ± 32.60 ms). Significant difference was marked with a star [$t_{(26322)} = -2.560$, $p = .017$, Levene's test = .004]. In terms of visual reaction time performance, the effect size between the offensive, and defensive players was 0.85 (large effect) according to Cohen's d [54].

According to Figure 5, the auditory reaction time performance was expressed in milliseconds in the boxplot chart. When the auditory reaction time of offensive (250.30 ± 28.38 ms) and defensive players (266.70 ± 35.37 ms) were compared, a statistically significant difference

was not detected [$t_{(33)} = -1.507$, $p = .141$, Levene's test = .181].

In Figure 6, the mixed reaction time performance is displayed in milliseconds in the boxplot chart. According to chart, there was no statistically significant difference between offensive (337.22 ± 28.92 ms), and defensive players (347.06 ± 55.54 ms) in terms of mixed reaction time [$t_{(25899)} = -.663$, $p = .513$, Levene's test = .030].

When looking at the box-plot chart in Figure 7, there was no statistically significant difference in comparing the perimeter length of offensive (529.06 ± 90.77) and defensive (514.65 ± 63.09) players. [$t_{(33)} = .548$, $p = .587$, Levene's test = .298]. Although not significant, it was found that dynamic balance performance of defensive players was better than offensive players.

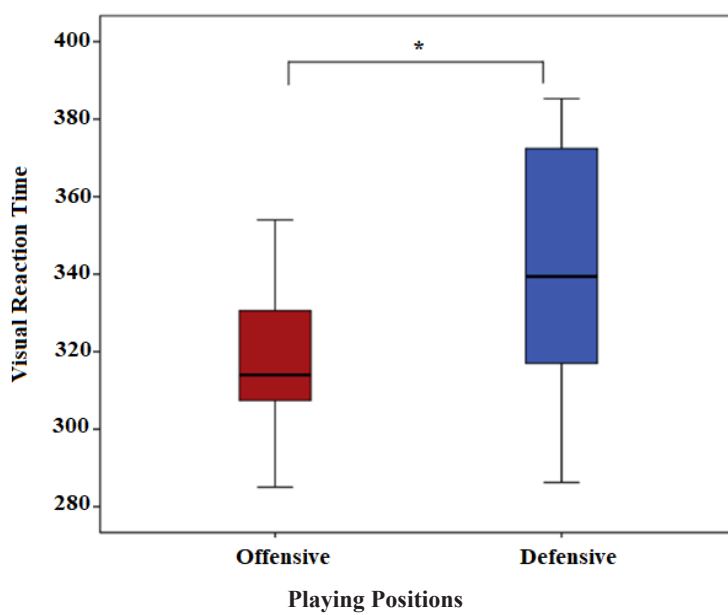


Figure 4. Comparison of Visual Reaction Time (ms) of players according to playing positions

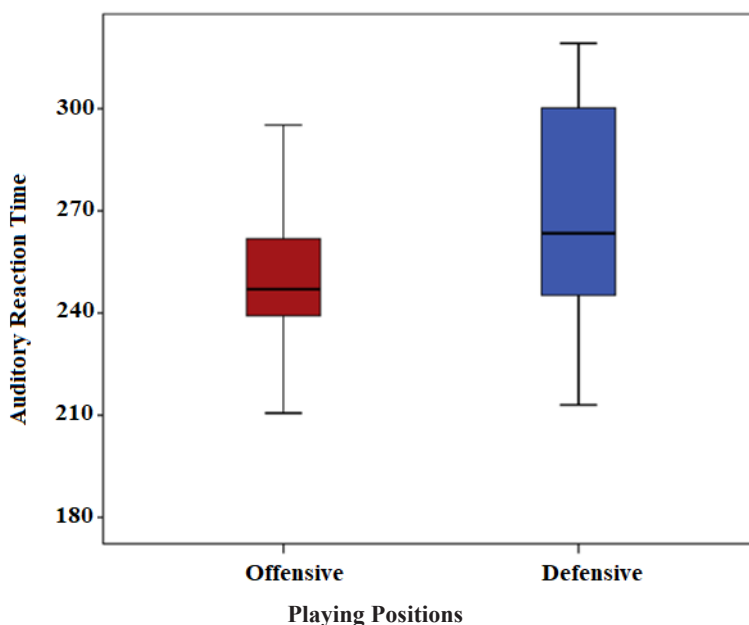


Figure 5. Comparison of Auditory Reaction Time (ms) of players according to playing positions

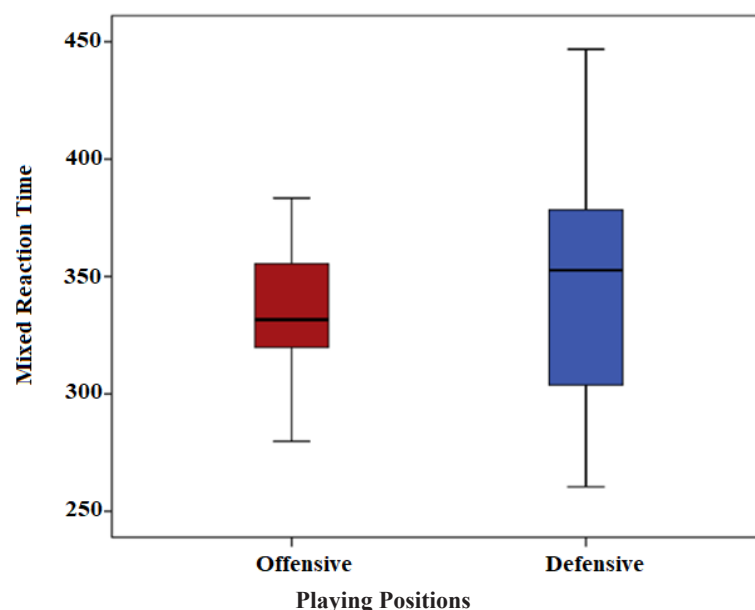


Figure 6. Comparison of Mixed Reaction Time (ms) of players according to playing positions

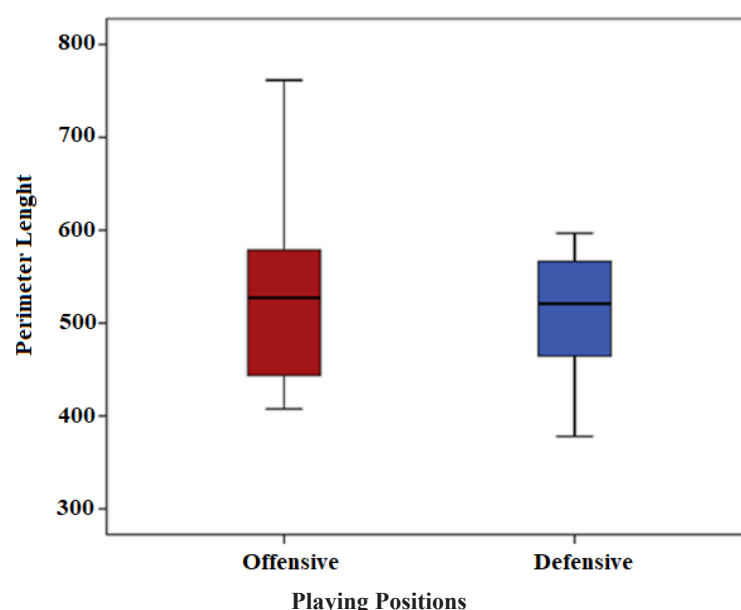


Figure 7. Comparison of Perimeter Length (°) of players according to playing positions

According to figure 8 shown in the form of a boxplot, the anterior-posterior balance performance of offensive and defensive players were found to be $-.41 \pm 2.81^\circ$, $-.24 \pm 1.60^\circ$, respectively. Although not statistically significant [$t_{(33)} = -.223$, $p = .825$, Levene's test = .056], it was observed that defensive players had better anterior-posterior balance performance than offensive players.

As shown boxplot in Figure 9, no statistically significant difference was found between offensive and defensive players in terms of comparing medial-lateral balance performance. Although not statistically significant [$t_{(33)} = 1.124$, $p = .269$, Levene's test = .828], the medial-lateral balance performance of defensive players ($.56 \pm 1.69^\circ$) was better than offensive players ($1.19 \pm 1.60^\circ$).

Discussion

The choosing the best answer, and making the fastest response during motor actions such as catching a moving ball/object, intercepting the action of the opposing team, an attempt to prevent the passing of the ball between the two players, and hitting the moving ball/object, and their implementation at the right time through the decisions made depends on the efficiency of the decision-making processes. For this reason, CAT performance is extremely important for the timely adjustment, and synchronization of the different motor actions occurring in the game in various sports branches [55]. The accurate and successful CAT performance depends on predicting an object moving dynamically, and in a timely manner, appropriate body movements towards the object, and position of the object when the response is completed. Otherwise, biased

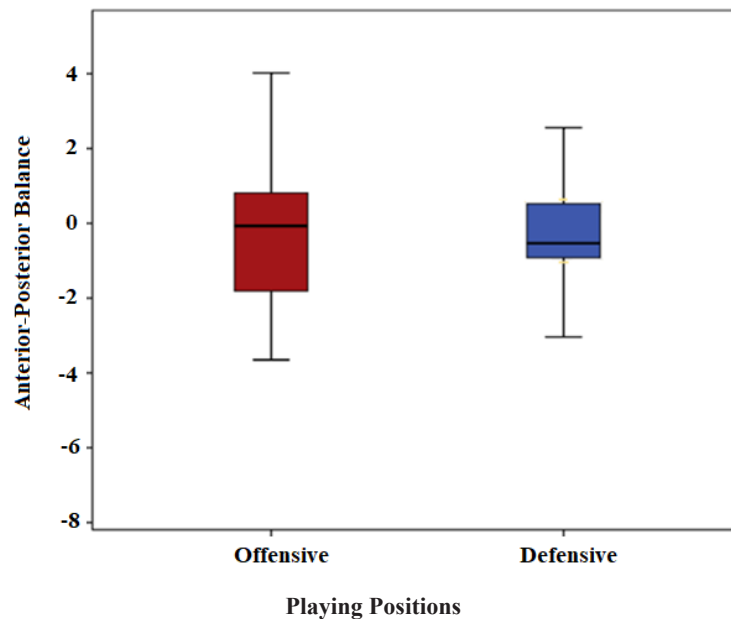


Figure 8. Comparison of Anterior-Posterior balance performance (°) of players according to playing positions

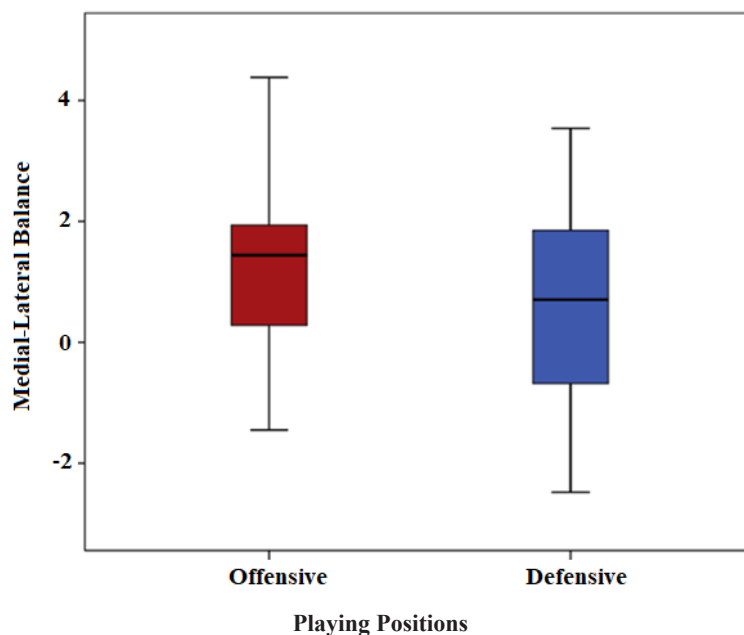


Figure 9. Comparison of Medial-Lateral Balance (°) of players according to playing positions

or wrong detection of moving object may cause temporal error [56].

Considering the results of this study, no statistically significant difference was found when the absolute error scores (6 mph) of offensive (20.35 ± 8.42 ms), and defensive (22.06 ± 7.14 ms) players were compared (Figure 2). Compared to defensive players (20.15 ± 3.81 ms), the absolute error score of offensive players (17.45 ± 3.48 ms) at fast stimulus speed (12 mph) were found to be significantly lower. This shows that the CAT performance of offensive players was better than defensive players. In addition, the effect size between the two groups was found to be 0.73. When this effect size is evaluated according to Cohen's d [54], it is at the "medium" level

(Figure 3). As compared with the low stimulus speed, the presence of a significant difference in the fast stimulus speed according to playing positions can be explained as follows; there is a relationship between the stimulus speeds, and variations in CAT performance. In a study, it was stated that the variations in response performance, ie the CAT performance, decreased as the speed of stimulus increased [48]. It has been suggested that the reason for this may be related to the information processing duration. At low stimulus speeds, the participant probably has greater difficulty in synchronizing the preparation of the action plan with the execution [57]. The participants seem to use the view as "feedback" due to the lower stimulus latency at slower speeds, and also they use their

“conscious perceptions” that focus on stimuli, and make their responses more reflective. Conversely, the response time at fast stimulus speeds is too short to allow more informed processing of the stimulus, and participants tend to respond more automatically, and they respond in the form of “feedforward” using the subconscious perception with the automations programmed in the motor region of the brain [48].

In literature, although there are studies examining the CAT performance in different sports branches such as soccer [58], volleyball [37, 59], the studies examining the CAT performance according to the playing positions in American football are quite limited. Saygin et al. [58] reported that the CAT performance at fast stimulus speeds was found to be better (not significant) especially in goalkeepers and forwards compared to other positions (defenders and midfielders). In another study, Gunay et al. [37] expressed that middle players who played for attack had better CAT performance at fast stimulus speed compared to outside players who play for defense. It was also indicated that the mid-players’ in-game combinations of offense, and block responsibilities played a very important role in having better predictive or CAT performance. Zhou et al. [59] determined that volleyball players playing in different positions used different strategies for visual search. Compared to other positions, they remarked that main offensive, and supporting offensive players used shorter search durations for their viewing time, which increased the accuracy of the prediction, and decision response. In addition, the high search speed in players playing in these positions was associated with high intensity of neural activation. These studies support the results of our research. In American football, each playing position has specific responsibilities [59]. Although the games are played within a certain tactical framework, the offensive players face different positions in the game according to the defensive players. In particular, running backs make continuous, and instantaneous decisions to move the ball forward, to predict the appropriate areas in the game, to maneuver at the right time without colliding with the opponent player to prevent possible injuries, and to score points. Besides, in order to advance the ball, they have to read the block of offensive linemen correctly. At the same time, quarterbacks analyze the game from a wide angle, identify the most suitable wide receivers meet the ball at the right time to score points or cover distance. Wide receivers need to predict the opponent’s movements and positions to overcome from the opponent, and move the ball as far as possible or to anticipate direction of the ball that doesn’t always come at the same intensity or height to catch the ball by quarter backs. As explained above, offensive players such as quarter backs, running backs and wide receivers take multi-faceted actions in the game due to the responsibilities of the characteristic structure of the game, and their playing positions according to defensive players. This can lead to improved processing ability of the central nervous system, and positively affect CAT performance at fast stimulus speeds.

Visual reaction time is related to how quickly a player

reacts to visual stimulus [46]. The reaction to actions quickly and at the right time in a dynamic environment within the game provides an advantage to the player in obtaining the desired results. According to the results of this study, the duration of auditory, and mixed reaction were found to be shorter although not significant compared to the defensive players (Figure 4 and 5), however, offensive players (318.11 ± 17.47 ms) were found to have a statistically significantly superior visual reaction time than defensive players (340.58 ± 32.60 ms). In terms of visual reaction time performance, the effect size between the offensive and defensive players was 0.85 (large effect) according to Cohen’s *d* [54]. (Figure 4). The studies examining reaction time performance by playing positions in American football are limited. The study was conducted on college American football players by Wylie et al. [10] found the overall mean response speeds, and accuracies of offensive (355 ms, 85.1%) and defensive (350 ms, 83.9%) players. The average values of reaction speed and accuracy were found close to each other. However, although the defensive players were good at the reaction speed, the response accuracy of the offensive players was higher. We can say that when a fast response is combined with a good decision making process, the desired result is obtained. The results of this research are not in line with Wylie et al. [10] research. The reason for this may be that the sample group differs in terms of physical and perceptual-cognitive characteristics. In a study, skilled position players (quarter backs, running backs, receivers, tight ends, safeties, defensive corner backs, punters, and place kickers) were reported to have faster reaction times than non-skilled position players (quarterbacks, running backs, receivers, tight ends, safeties, defensive corner backs, punters, and place kickers), and offensive players are defined as skilled position players, and support the results of this research [24]. In addition, having fast reaction time in American football prevents possible collisions or injuries. In a study, it has been found that players with slow reaction times were slower to prepare for the collisions, and as a result they experienced higher magnitude head impacts [60]. Fujii et al. [61] notified that the players who keep the body of the opponents in the central view, and the position of the contact foot in the peripheral field of view were very likely to predict the actions of the opponents, and accordingly they reacted faster [61]. The CAT and reaction time performance are related perceptual-cognitive characteristics. Therefore, the fact that CAT performance was superior in offensive players may also have affected their visual reaction time. The offensive players such as quarter backs, running backs, and wide receivers have to communicate with each other in seconds, and need to produce extra perceptual-cognitive solutions except tactics to pass the defensive players, advance the ball or score points. In this very short period of time, in order to have a quick reaction, they necessitated to analyze the movements of the ball, each other, defensive players, and even the general characteristics of the games correctly. The challenging perceptual-cognitive demands of the game,

and the variety of positions that they face are different in offensive players as compared with defensive players. For such reasons, the reaction time of the offensive players may be shorter than defensive players. In literature, it was propounded that short response time of the high level players to the reactions in different sports branches may be due to the functional characteristics associated with the demand of their playing positions [38], the structural and functional characteristics of the middle temporal area sensitive to the visual movement [62], and the effect of the dynamic sensorimotor demands associated with sports on the central nervous system [63].

The dynamic balance performance is an important prerequisite for an athlete's performance and for the prevention of injury risks in sports. The deficiencies in dynamic balance can lead to body instability, overloading of musculoskeletal structures that cause dysfunction and pain [64]. Since American football is a collision-based sport, the risk of injury is very high. The dynamic balance test measurements such as The Star Excursion Balance Test, Functional Movement Screen and Y-Balance Test are common and reliable tests used to evaluate the injury risk of lower limb injury, neuromuscular control, and core stability, lower limb balance performance, and asymmetries in American football [29, 65, 66, 67]. In previous studies was shown that American football players with increased asymmetry in dynamic balance had a higher risk of contactless musculoskeletal injuries in the lower limbs [68], and contactless injuries to the knee or ankle [69]. There are a limited number of studies in the literature comparing dynamic balance performances of American football players according to their playing positions. According to the results of this study, no statistically significant difference was detected in the comparison of the dynamic balance parameters of the offensive and defensive players such as perimeter length, anterior-posterior, and medial-lateral. Although not significant, the dynamic balance performance of the defensive players was found to be better than the offensive players ($p>0.05$). (Figure 5-9). This can be explained as follows; defensive players such as defenseline and linebackers try to defend by lowering their center of gravity in order to drop the offensive players or win the ball in line with the tactical understanding of their playing positions. The defensive players by constantly lowering their center of gravity may contribute to the development of their dynamic balance skills. In further studies, by increasing the sample size, repeating this study may lead to a significant difference in balance performance between playing positions. Bizid ve Paillard [70] detected that anterior posterior dynamic balance in a non-learned standardized balance task in eyes open condition differed between offensive and defensive soccer player in favor of the defensive players. They also reported that defensive players were more successful in balance tasks that require postural compensatory activities as they are more trained to respond to the attacks of offensive players, and try to tackle the opponents directly. The conclusion and interpretation of Bizid and Paillard [70] research is

partially consistent with the results of this study. In another study, it was demonstrated that players who participated in contact sports like football and American football had superior postural control during difficult unipedal stance compared to players who participated in limited contact sports such as baseball. When visual information was interrupted, it was observed that contact athletes were not affected much in terms of balance, and their balance performances were not dependent on visual system. This is due to the fact that contact athletes used information from the sensorimotor, and vestibular system to maintain balance when visual information was interrupted. Since sensory systems change in environmental conditions in contact sports such as American football and soccer, it is important to improve proprioceptive and vestibular functions related to maintaining balance due to sensory re-weighting [71].

Conclusions and Recommendations

It was shown with studies that the physical and motoric characteristics of American football players were different according to their playing positions. In addition to these characteristics, the perceptual-cognitive characteristics of American football players differ when evaluated according to their playing positions. This difference was demonstrated by this study. The offensive players of CAT performance at fast stimulus speeds (12 mph), and visual reaction time were found to be better as compared with defensive players. The reason for this is due to the demands of their playing position, such as the playing position of offensive players to defeat defensive players, and score points requires multi-faceted thinking in games, and to try out many different combinations of strategies in an environment with many stimuli. The CAT and reaction time are important for both offensive and defensive players. Therefore, it is considered important to include more specific exercises, video-based perceptual exercises, and visual training to improve these characteristics for both the playing positions especially defensive players in training or non-training times as well as physical training. American football is a collision-based sport that consists of intermittent high intensity activities, so the risk of injury is very high. In order to reduce the risk of injury in the both playing positions in the games, it is recommended to measure the pre-season balance performance of players, and to plan programs for this sport-specific neuromuscular, proprioceptive exercises, and dynamic balance exercises that improve the integration between the vestibular-visual system (eyes-open, eyes-closed, stable floor, and unstable floor). In the literature, Nine playing positions have been defined for American football. The offensive and defensive players are divided into positions within themselves. In the further studies, it is suggested to increase the sample size, and evaluate the CAT, reaction time, balance skills, and different perceptual-cognitive parameters (visual perception, executive function, visual control, attention, focussing etc.) taking into account all playing positions.

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Conflicts of Interest

The authors declare no conflict of interest.

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The effect of elbow position on the handgrip strength test in children: validity and reliability of TKK 5101 and DynX dynamometers

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Abstract

Purpose: One of the most widely applied methods to assess upper-body strength in children and adolescents is the handgrip strength test. While in adolescents it has been determined which elbow position, and which type of dynamometer are most appropriate for achieving the maximal grip strength, in children is still not clear. Therefore, the purpose of this study was to investigate whether elbow position and the type of dynamometer affect the handgrip strength in children.

Material: Grip strength was measured by TKK and DynX dynamometers, and their validity and reliability were also analysed. A total of 60 children, 6 to 11 years old, participated in this study, and performed the handgrip strength test with their elbow extended and flexed at 90°.

Results: While using the TKK dynamometer, grip strength was significantly higher when the test was performed with elbow extended, in contrast to those obtained with elbow flexed (14.58±3.04 kg vs 12.97±2.99 kg, $p<0.001$ for right, and 14.25±3.05 kg vs 12.61±2.99 kg, $p<0.001$ for left hand). Likewise, when using the DynX dynamometer, the difference between the two elbow positions was smaller but still significant (13.84±3.22 kg vs 13.35±3.01 kg, $p=0.035$ for right, and 13.35±2.95 kg vs 12.77±2.96 kg, $p=0.003$ for left hand).

Conclusions: Both dynamometers provided sufficient results in terms of their reliability and the TKK dynamometer showed to be more valid. Performing the handgrip strength test with elbow extended appears to be the most appropriate position in order to obtain maximal results in children.

Keywords: physical fitness, maximum grip performance, dynamometry, Bland and Altman.

Introduction

Muscular strength is the ability to perform activities which require a high level of muscular force and has been one of the main components for assessing health-related physical fitness [1]. Systematic reviews show that there is strong evidence that improvements in muscular strength from childhood to adolescence are inversely proportional to changes in overall adiposity later in life [2, 3]. There is no single test for measuring muscle strength, because the maximum force which can be generated depends on several factors, such as the size and number of muscles involved, the proportion of muscle fibres in action, and the coordination of the muscle groups [4]. However, the most commonly performed test is the handgrip strength test [1, 4], which appears to be a widely-used method to measure upper body isometric strength in children and adolescents [5-9].

Handgrip strength has been shown to be influenced by different factors, such as gender, age, positions of the shoulder, elbow, forearm and wrist [10-12], posture [13, 14], as well as grip span and hand span [4, 15-18]. It is not clear which elbow position is most appropriate for achieving the maximal handgrip strength, owing to inconsistent findings [19-23]. While the American Society of Hand Therapists supports the 90° flexed elbow

position [24], the American Centers for Disease Control and Prevention (CDC) recommends that the test should be performed with a straight elbow [25]. Furthermore, other findings show that maximal handgrip strength was achieved with flexed elbow at 135° [26]. Most studies on the influence of elbow position with regards to the assessment of handgrip strength have been conducted with adults [21, 23] or elderly people [20]; however, studies on the effect of elbow position in youngsters are scarce. For instance, it was reported that the most appropriate protocol for assessing handgrip strength, in adolescents between the ages of 12 and 16, is with elbow in full extension [27], but in children this has not been investigated yet.

Studies on handgrip strength have been conducted by using different hand dynamometers, such as: TKK digital dynamometer, Jamar hydraulic dynamometer and DynX electronic dynamometer. The validity and reliability of these common dynamometers were reported in several studies [28, 29], but they were mainly conducted by using correlation coefficients, which is not considered as the most appropriate method for that purpose [30, 31]. An alternative approach, based on graphical techniques and simple calculations for assessing agreement between two different methods, which was provided by Bland and Altman [32], is commonly used for that purpose. Based on this approach, studies on test and retest were conducted mainly with the TKK dynamometer, which was shown

to be reliable by producing a mean difference of less than 0.25 kg [33-36], that is lower than the precision of an average analog dynamometer (i.e. 0.5 kg). However, differences amongst instruments (type of dynamometers) and duration between measures might have an effect on the precision of a dynamometer [35]. Furthermore, when different models of the TKK dynamometer were measured, the systematic error between different instruments of the same model and between different models (digital vs. analog) was reported to be between 0.3 kg and 0.6 kg, and the systematic error between new and old dynamometers ranged from 0.8 kg to 1.1 kg [37] which can be quite significant. The TKK dynamometer showed the lowest systematic error and the highest criterion-related validity and reliability in comparison to the Jamar and DynX dynamometers, when tested vs known weights within the range of 5-65 kg [27]. However, the Bland and Altman plots in the same study suggest that these results might be different in the range of the children's grip strength (5-30 kg) for the DynX dynamometer. Although, the TKK dynamometer provided the highest validity and reliability (vs other dynamometers, such as Jamar), further research involving different types of dynamometers (e.g. Jamar, DynX), especially focused on the range of the children's handgrip strength (5-30 kg), are needed in order to confirm these findings [37].

Therefore, the purpose of our study was to investigate whether elbow position affects the handgrip strength in children (6 – 11 years of age), and to analyze the validity and reliability of widely applied dynamometers, TKK and DynX vs known weights, within the range of the children's strength (5-30 kg).

Material and methods

In order to examine whether the elbow position affects the handgrip strength in children, grip strength measurements of two different elbow positions were compared (at full extension and flexed at 90°) by implementing two different hand dynamometers, TKK digital hand dynamometer and DynX electronic hand dynamometer. The Bland-Altman method was applied in order to analyze the validity and reliability of the TKK and DynX dynamometers vs known weights within the range of the children's handgrip strength (5-30 kg).

Participants

In this study a total of 60 children participated (30 boys and 30 girls) from 6 to 11 years of age. The research was carried out at St Edmund's Primary School in London, United Kingdom. Letters with information about the nature and the purpose of the study were given to the children and their parents/guardians. Written informed consent was obtained from the parents prior to testing. The protocols from this study were performed in accordance with the ethical standards established in the WMA Declaration of Helsinki (revised in Fortaleza, Brazil, in 2013).

Procedures

Handgrip strength was measured with two different dynamometers:

1. TKK digital hand dynamometer (TKK 5101 Grip-D, Takey, Tokyo, Japan), which has an adjustable grip span ranging from 3.5 to 7 cm with a precision of 0.1 kg [5].
2. DynX electronic hand dynamometer (MD System, Inc., Westerville, OH, USA), which has 3 grip



Fig. 1. Handgrip strength test with fully extended and flexed elbow, using TKK (above) and DynX (below) dynamometers

positions (4.75 cm, 6 cm, and 7.25 cm) with a precision of 0.1 kg [38].

The optimal grip span was determined for every child according to their hand size by employing the equations developed by Espana-Romero et al. [15], and the grip position of the TKK dynamometer was adjusted to each individual prior to testing. The second grip position (4.75 cm) was used for the DynX dynamometer [28, 38].

Two different tests with each dynamometer were performed. The first test was with the elbow at full extension, and the second with flexed elbow at 90°. Standard procedures were followed for both tests [5, 27]. In brief, during the assessment with straight arm, children were asked to keep their elbow at full extension, the forearm in neutral position, with the wrist extended. When performing the test with bent elbow, the forearm was in neutral position and the elbow joint at 90°. Both tests were performed with feet shoulder-width apart in standing position, and children were given instructions not to touch any other part of the body with the dynamometer, except the hand being measured.

Each test was performed twice, with the left and right hand alternately. During the tests, the elbow position, the hand being tested, as well as the dynamometer were chosen randomly. Children were encouraged to squeeze gradually, continuously, and as hard as they can for at least two seconds, with a rest period of at least 60 seconds between tests and at least 5 min between dynamometers.

Validity and reliability

The comparison between dynamometers and known weights (validity) and repeated measurements (reliability) of the TKK and DynX dynamometers were analyzed by using known weights within the range of the children's grip strength (5–30 kg, every 5 kg). The weights were verified by using an electronic scale with an accuracy of 0.05 kg. The weights were held with a belt (5 cm width and weight of 200 ± 1 g, which was taken into account), and they were measured twice in random order. In order to assess whether there was systemic bias, the deviation of the average differences of measurements from 0 was analyzed by one-sample t-test.

Statistical Analyses

The Kolmogorov-Smirnov test of normality was applied in order to examine the distributions of handgrip strength values. Paired t-test for dependent samples was used in order to compare the differences between the elbow positions (full extension vs flexed at 90°). Statistically significant differences between the average

results were evaluated at $p < 0.05$, and all data in the text are presented as mean ± SD. In addition, Cohen's effect size of the handgrip strength values with elbow at full extension vs flexed at 90° were also calculated in order to present the magnitude of the effects. The following classification of the effect size was applied: $d (0.01)$ = very small, $d (0.20)$ = small, $d (0.50)$ = medium, $d (0.80)$ = large, $d (1.20)$ = very large, and $d (2.00)$ = huge [39, 40]. Percentile scores for the average handgrip strength of both hands were calculated by using the available gender- and age- specific interpolated European norms for children and adolescents [41]. All the analyses were performed for both boys and girls together because there was no interaction between gender and elbow position, and gender and type of dynamometer.

The Bland-Altman method was used to analyze the validity and reliability of the TKK and DynX dynamometers. This method is considered appropriate for studying the agreement of 2 measurements [32]. Moreover, the systematic bias, 95% confidence intervals of the bias, and the 95% limits of agreement (bias ± 1.96 SD of the differences) were also computed.

Results

The Kolmogorov-Smirnov test showed normal distribution for all variables. The results from the handgrip strength test obtained with each dynamometer, and each hand and elbow position, are presented in Table 1. Handgrip strength was significantly higher when the test was performed with elbow extended, in contrast to the results obtained with flexed elbow at 90°, while using the TKK dynamometer (14.58 ± 3.04 kg vs 12.97 ± 2.99 kg, $p < 0.001$ for right hand, and 14.25 ± 3.05 kg vs 12.61 ± 2.99 kg, $p < 0.001$ for left hand). Furthermore, Cohen's effect size values were 0.87 for right hand, and 0.91 for left hand. When using the DynX dynamometer, the difference between the two elbow positions was smaller, but still significant, in favour of the fully extended elbow position (13.84 ± 3.22 kg vs 13.35 ± 3.01 kg, $p = 0.035$ for right and, and 13.35 ± 2.95 kg vs 12.77 ± 2.96 kg, $p = 0.003$ for left hand), and the effect sizes were small to moderate ($d = 0.28$ and $d = 0.41$, respectively).

The data did not change much after adding up the results obtained with both hands (Figure 2). The children's grip strength was significantly higher when the test was performed with full extension, in contrast to bent elbow position using TKK dynamometer (28.83 ± 5.85 kg vs 25.58 ± 5.69 kg, * $p < 0.001$), as well as using DynX

Table 1. Handgrip strength according to the type of dynamometer and hand and elbow position (at full extension and flexed at 90°) in children aged 6 to 11 years ($n = 60$), Mean ± SD

Dynamometer	Hand	Extended	Flexed	Difference	Percent Difference	p
TKK	Right	14.58 ± 3.04	12.97 ± 2.99	1.61 ± 1.85	11.02%	< 0.001
	Left	14.25 ± 3.05	12.61 ± 2.99	1.64 ± 1.81	11.52%	< 0.001
DynX	Right	13.84 ± 3.22	13.35 ± 3.01	0.49 ± 1.77	3.56%	0.035
	Left	13.35 ± 2.95	12.77 ± 2.96	0.57 ± 1.40	4.28%	0.003

dynamometer (27.19 ± 5.86 kg vs 26.12 ± 5.73 kg, * $p < 0.001$). Additionally, significantly higher results were registered when using TKK dynamometer with full extension in comparison with DynX dynamometer with elbow flexed at 90° , † $p < 0.001$ (Figure 2).

Percentile scores (PRs) of the average handgrip strength in both hands, based on the most recent norms in European children [41], were calculated from the values obtained by the TKK dynamometer with straight elbow position, because these results showed the highest values. The mean percentile score for all participants was 54.0 ± 28.0 , and ranged from 5.2 to 98.1, which shows that the sample represents the whole range of possible handgrip values (9.0 – 21.2 kg) in children from 6 to 11 years of age.

The validity and reliability of the TKK and DynX dynamometers were analysed by using known weights within the range of the children's possible handgrip strength (5-30 kg). The criterion-related validity analyses showed a non-significant systematic bias of -0.20 kg ($p > 0.05$) for the TKK, and a significant systemic bias of -0.42 kg ($p < 0.001$) for the DynX dynamometer. The 95% limits of agreements were 0.62 kg for the TKK dynamometer, and 0.46 kg for the DynX dynamometer (Fig.3).

The reliability analyses revealed a non-significant systematic bias of -0.07 kg in the TKK, and 0.10 kg in the DynX dynamometer ($p > 0.05$ for both dynamometers), and the 95% limits of agreements were 0.27 kg, and 0.25 kg, respectively (Fig.4).

Discussion

The handgrip strength test is part of many health-related physical fitness test batteries in children [5, 8, 42-

44], in addition to being widely used in experimental and epidemiological research [7, 45, 46], as well as throughout a range of groups practising sports [47, 48]. Therefore, it is of particular importance to standardize the procedure of this test in order to prevent measurement errors.

To the best of our knowledge there have not been any research focused on whether the elbow position affects handgrip strength in children between the ages of 6 and 11 when using TKK or DynX dynamometers. The results from this study, showing that handgrip strength is higher with full extension in comparison to bent elbow, are in agreement with a number of authors who investigated this issue in adolescents [27] and college students [19], as well as the recommendation by the American Center for Disease Control and Prevention (CDC) to perform the test with straight elbow [25].

Espana-Romero et al. [27] explains the higher handgrip values produced by the TKK dynamometer in comparison with other dynamometers, partially by the fact that the grip span of this dynamometer is accurately adjusted to the adolescent's hand size by using the equations of Ruiz et al [18]. In our study we applied the equations adjusted for the hand size of children [15] when using the TKK dynamometer, and we also observed greater handgrip strength values in favour of the TKK vs the DynX dynamometer.

The greater difference between the recorded values with straight and bent arm, obtained with TKK vs DynX dynamometer in our study, might be explained by the influence of the dynamometer's weight and the greater distance of the tool from the hand grip, which is apparent especially for the TKK dynamometer. This might negatively influence the handgrip strength produced

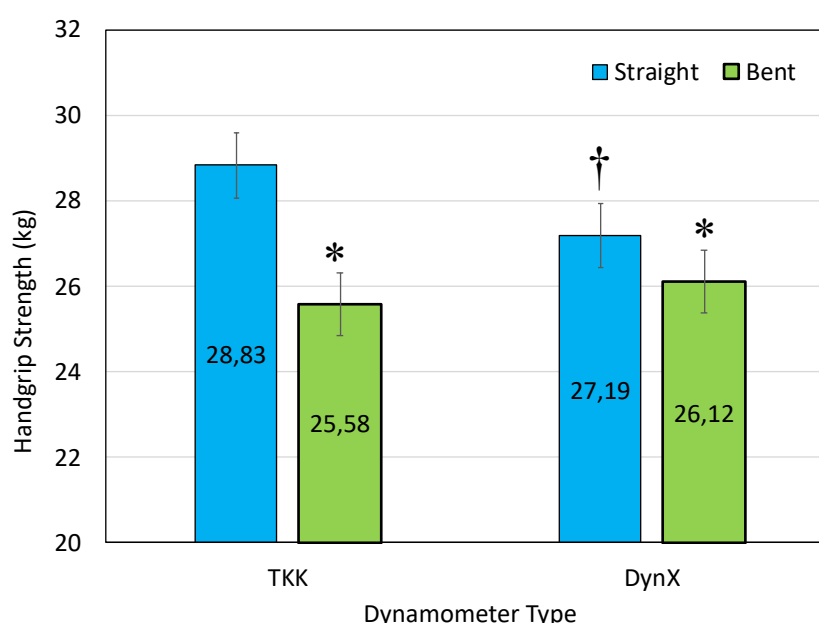


Figure 2. Comparison of handgrip strength measured with elbow at full extension (blue) and with elbow flexed at 90° (green) in children aged 6 to 11 years ($n = 60$). Sum of right and left hand scores is shown, and was used for analyses. Data are expressed as mean $\pm$ SE. * $p < 0.001$ vs elbow at full extension. † $p < 0.001$ vs TKK dynamometer with elbow at full extension.

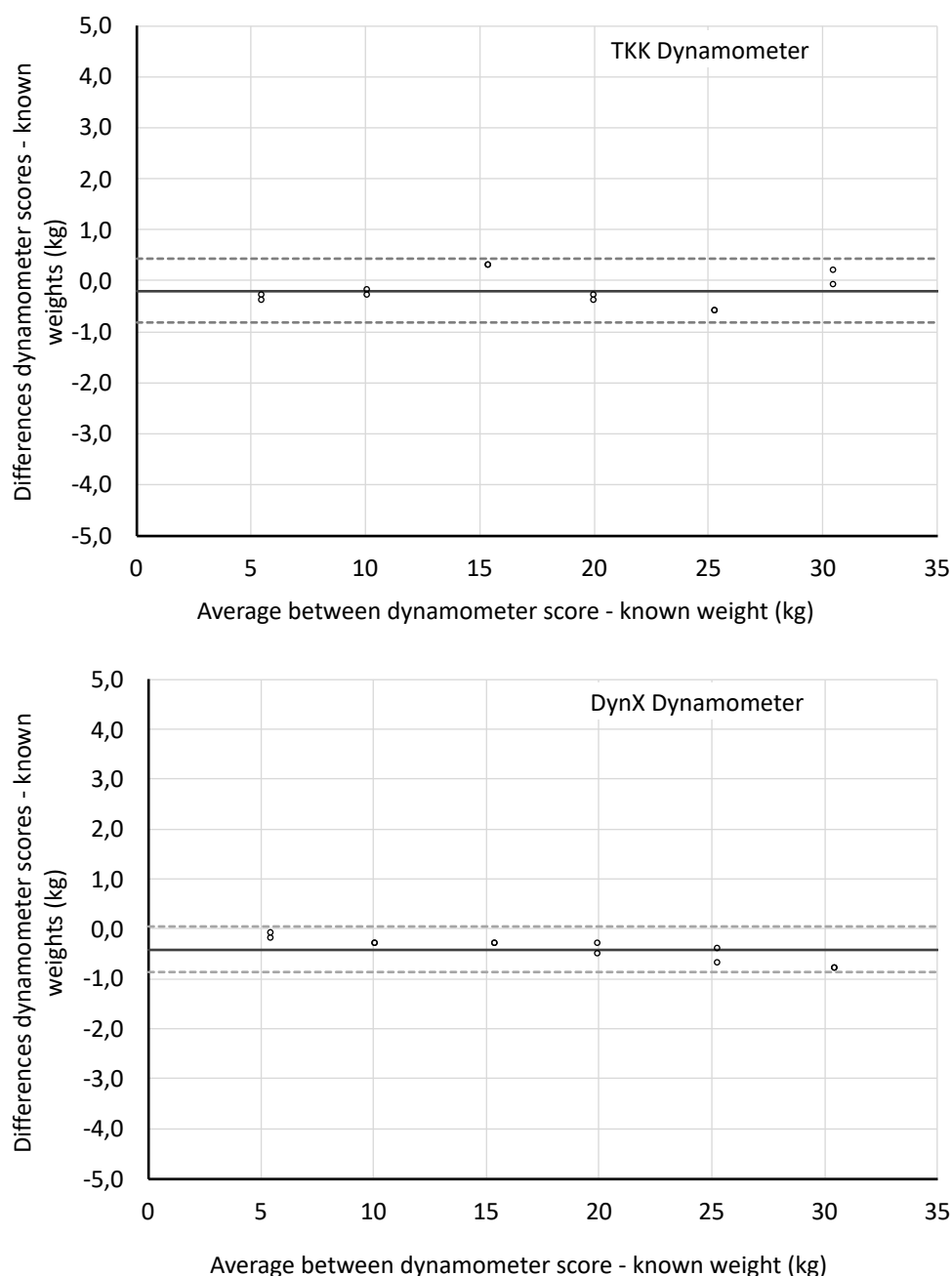


Figure 3. Validity between the TTK and DynX dynamometers and known weights by Bland and Altman plots [32]. The central line shows the mean difference (bias) between the dynamometer weight score and the known weight. The upper and lower lines represent 95% limits of agreement (mean difference $\pm$ 1.96 SD of differences).

with bent elbow, specifically in children. This effect is smaller for the lighter dynamometer, DynX. When handgrip strength is assessed by using lighter (DynX) and shorter (Jamar) dynamometers in older individuals, such as adolescents [27] and young adults [26], no significant difference between the straight and bent elbow positions was reported.

Espana-Romero et al reported that the DynX dynamometer underestimates the handgrip strength levels (-1.43 kg, $p < 0.05$), and the TTK dynamometer slightly overestimates handgrip strength (0.49 kg, $p < 0.05$) when analysed vs known weights between the ranges of 5 to 70 kg, but these systematic biases are more visible after reaching a handgrip strength above 40 kg [27]. In the

present study, the validity analyses within the range of the children's possible handgrip strength (5-30 kg) suggested a systematic error for the DynX dynamometer (-0.42 kg, $p < 0.001$), but this underestimation is lower than the precision of an average analog dynamometer (i.e. 0.5 kg). Our findings also suggested a non-significant systematic bias of -0.20 kg ($p > 0.05$) for the TTK dynamometer, which is in agreement with Espana-Romero et al. within the range of 5-30 kg [27]. In contrast, the reported results in a recent study on validity of different models of TTK dynamometers (2 new digital, 1 old digital, 2 new analog and 1 old analog) vs known weights suggested that all of the TTK models underestimates the handgrip strength from -0.94 kg to -2.64 kg [37]. However, the authors

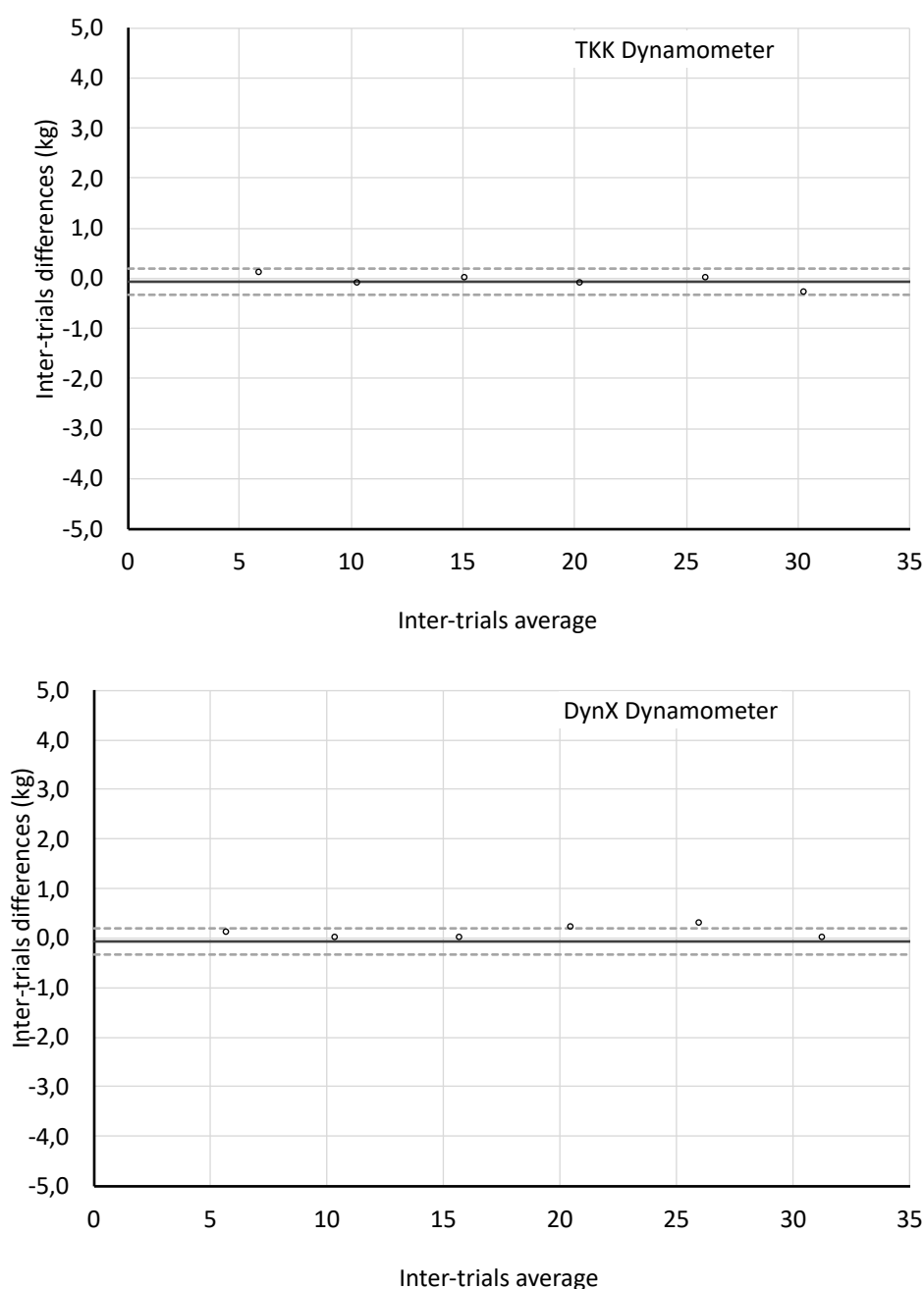


Figure 4. Reliability of weight trials of TKK and DynX dynamometers by Bland and Altman plots [32]. The central line shows the mean difference (bias) between the dynamometer weight score and the known weight. The upper and lower lines represent 95% limits of agreement (mean difference $\pm$ 1.96 SD of differences).

believe that this underestimation could be due to the scale used to measure weights.

The reliability analyses in our study suggested a systematic bias of -0.07 kg in the TKK, and 0.10 kg in the DynX dynamometer ($p > 0.05$ for both dynamometers), similar to those reported in other studies: 0.02 kg for the TKK and 0.26 kg for the DynX dynamometer ($p > 0.05$) [27]; -0.20 kg ($p > 0.05$) for the TKK dynamometer [36]. Overall, studies on test and retest of the TKK dynamometer showed consistency with a mean difference of less than 0.25 kg between trails [33-36]. However, when repeated measures are taken by using different TKK dynamometers (e.g., two digital dynamometers) or different models (e.g., digital vs analog), the systematic

error is expected to range from 0.3 to 0.6 kg [37].

Conclusions

In conclusion, performing the handgrip strength test with elbow extended appears to be the most appropriate protocol in order to evaluate maximal handgrip strength in children. Both, TKK and DynX dynamometers provided sufficient results in terms of their reliability within the range of the children's handgrip strength, and the TKK dynamometer showed to be more valid.

Conflict of interests

The authors declare that there is no conflict of interests

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The influence of professional training disciplines on the physical fitness level of the folk dance department students

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Abstract

Purpose: To determine the influence of professional training disciplines on the physical fitness level of the folk dance department students.

Material: The study involved students majoring in "Choreography" (males - n = 5; females - n = 10). Tests were used to determine the level of general and special physical qualities development. It was also determined the level of physical fitness at the beginning of training and after two years of training.

Results: At the beginning of the study, students had average and low rates of speed and strength qualities development and low indicators of dorsal spine mobility. There were significant changes in increasing the level of coordination and dorsal spine mobility ($p < 0.01$). The increase in average statistical indicators of strength endurance is in males ($p < 0.05$) and females ($p < 0.01$). It was revealed the decrease in the level of certain indicators of general physical fitness in females during the first two years of study.

Conclusions: It is recommended to constantly monitor the physical fitness of future choreographers. The exclusion of the discipline "Physical Education" from the training programs for choreography teachers requires appropriate compensation for specific physical activity. These can be students' independent physical training. It also requires the correction of special training programs that include physical activity.

Keywords: physical fitness, choreography, professional training, professional disciplines, teacher.

Glossary:¹

Aplomb - Ability to keep all parts of the body in balance. Confidence and freedom of dance performance.

Exercise - The first part of a classical dance lesson. Movements near barre and in the middle of the hall in the appropriate sequence. They form and improve professional qualities for performing dance technique: turnout ability, leg muscle strength, body posture, head, hands, coordination, aplomb.

Allegro - Part of a classical dance lesson, which consists of jumps (low, average, high).

Allonge - Position in classical dance. It is based on the principle of straightening the rounded positions of the hands (*arrondi*).

Plie - Bent, bending. A bending of the knee or knees. This is an exercise to render the joints and muscles soft and pliable and the tendons flexible and elastic, and to develop a sense of balance.

Arabesque - One of the basic poses in ballet. In ballet it is a position of the body, in profile, supported on one leg. *Sissonne Fermée* - Closed *sissonne*. A step of low elevation performed to a quick tempo.

Port De Bras - Carriage of the arms. The term *port de bras* has two meanings: (1) A movement or series of movements made by passing the arm or arms through various positions. The passage of the arms from one

position to another constitutes a *port de bras*. (2) A term for a group of exercises designed to make the arms move gracefully and harmoniously.

Introduction

The deterioration of students' health is due to the socio-economic environment, reduced physical activity, insufficient motivation for a healthy lifestyle, lack of a culture of self-development of individual physical qualities. In this context, the problem of the physical fitness of students in higher education institutions becomes especially important.

The majority of young people have a low level of physical fitness; no need for physical exercise and mastering the values of physical culture [1, 2, 3]. The physical fitness of the folk dance department students is an indicator of readiness for physical activity, provided by the educational program in the major "Choreography". The level of physical fitness creates a basis for further development of technical and stage qualities of future professionals.

Kuznetsova et al. [4] determined the level of physical fitness of 1st-year students of the university: 37% - had lower than average; 21% - average; 28% - low. The comparative analysis of students from different higher education institutions did not reveal a high level of physical fitness [5]. The author found out that the lowest level of indicators is observed in aerobic endurance. Shchur [6] determined the level of physical condition

in art specialties students. The author proves that it corresponds to the average level. Marinchuk [7] revealed the features of physical fitness in creative specialties students. The author found out the decrease in indicators during training. The need for strength endurance and dorsal spine mobility development is also substantiated.

The improving choreographic skills lead to the search for adequate approaches to the professional and practical training of future teachers of choreographic disciplines. The choreographic activity combines a high level of performance and high artistic and emotional culture. The requirements for the overall quality of choreographers' training are becoming higher [8]. Choreographic training includes a set of disciplines that form a range of professional competencies.

The main criteria of professional selection of choreographers for training in educational institutions are the following: health, turned foot, dorsal spine mobility, plié, maximum leg height, the ability to jump high, coordination [9]. Most authors prefer dorsal spine mobility. It is a necessary condition for the graceful performance of dance movements. Petrovich et al. [10] determined that after 13-14 years it is necessary to perform stretching exercises. Under other conditions, dorsal spine mobility can decrease significantly in 16-17 years. Namely, this age category of students is the largest in the 1st year of study.

The asthenic type of the dancer's body is preferred in the choreography art: graceful lines, long legs, narrow shoulders, short torso, feet turned outwards. These requirements are caused not only by the aesthetic principles of the art of dance. The dancer's body balance makes it easier to overcome the load and overload of professional activity. Also, the choreographer needs muscle strength [6, 11]. It allows performing the complex of physical exercises with external resistance or response. Blagova [12] emphasized that the professional competencies of a choreographer are an organic combination of essential professional characteristics, personal significant qualities, and abilities.

The following competencies of the future teacher of choreography are the same important: physical endurance; motor activity; agility; ability to distribute different types of physical activity; perform relax exercises; to use in practice the knowledge of physical culture, anatomy, physiology, hygiene, medicine [13-15]. The professional activity of a choreographer is associated with high motor activity and excessive physical activity [16, 17]. Strength endurance is an important guarantee of a dancer's health and creative longevity.

The ability of aplomb in choreography is an important component of professional growth. This is performed in the ability to fix a given position in space [17]. The sense of balance is important for performing many movements and poses of different types of dance.

It is recommended to include in choreographic training exercises of general and special physical training [17, 18]. This expands the ability to adapt to unexpected changes in professional activities. It also promotes body recovery

and increases readiness for modern living requirements.

The study of the plyometric training impact on improving the physical fitness of choreographed students showed the following: increasing the explosive strength of the legs (37%); vertical jump height (8.3%); abdominal strength (22%) [18]. The work of all muscles and joints is subordinated to the basic movements of modern ballroom dance. They include the "complex of special exercises" for the whole body: coordination movements complex in European dance program ("slow waltz", "tango", "slow foxtrot", "quick step", "Viennese Waltz") and Latin American dance program ("samba", «Rumba», «cha-cha-cha», «pasodoble», «jive») [17].

Modern dance is an effective means of physical training. It is a synthesis of physical culture and art [19, 20]. The study of different styles of modern dance (*contemporary, modern dance, jazz dance, hip-hop, jazz fank*) involves mastering the various techniques of working with the body, breathing, consciousness.

The professional training of future choreography teacher is comprehensive [21, 22]. It includes the special disciplines' mastering by students. These disciplines are aimed at forming the basic qualities of a teacher, dancer, choreographer-director. The majority of educational institutions independently develop a training program for dance specialists. There is a need to implement an effective educational program that can ensure sufficient physical development of students. This approach makes it possible to improve the professional ability to perform professional functions.

The cycle of professional training of choreographers is aimed at the formation of the following competencies: improving the practical skills of choreographic performance, dance improvisation, work with movement and its various forms; ability to reproduce dance movements and compositions in an ensemble. Considerable attention in professional disciplines should be paid to the development of physical qualities of students (special coordination of movements, dorsal spine mobility, muscle strength, agility, and endurance). The student's physical fitness is one of the criteria of health and an important factor in his professional training effectiveness. Consequently, the method of organizing and conducting practical professional training requires improvement. It is also necessary to search for the new forms and methods of conducting training and organizing the educational process.

The purpose of the study is to determine the influence of professional training disciplines on the physical fitness level in folk dance department students.

Material and Methods

Participants. The study involved students (males - $n = 5$; females - $n = 10$) majoring in "Choreography" (Faculty of Arts, Folk Dance Subdivision, H.S. Skovoroda Kharkiv National Pedagogical University, Ukraine). At the beginning of the study, the average age of participants was 17.2 ± 1.8 years.

Research Design. The study was conducted for two

years at the Choreography Department (H.S. Skovoroda Kharkiv National Pedagogical University, Ukraine). The students have 16 hours per week of professional disciplines. In September 2017 and in September 2019, the same students took the tests. Educational program for student's training exclude the discipline "Physical Education". The development of physical qualities is the task of special disciplines in the course of professional training. The distribution of general and special physical activities of the training class in percentage is the following:

- 1) General warm-up - 10%;
- 2) Bar-work *exercice* - 20%;
- 3) *Exercices* in the middle of the hall, with allegro - 20%;
- 4) trick elements and spins - 20%;
- 5) Study and improvement of dance exercises - 15%;
- 6) Stretching exercises and floor barre - 15%.

The general physical fitness (GPF) of students was determined using the following exercises:

Test 1. 4x9 m Shuttle test, sec. [23, 24].

Test 2. Standing Long Jump Test (Broad Jump), cm [23, 24].

Test 3. Vertical Jump Test (Sargent Jump), cm. [25, 26].

Test 4. President's Challenge Curl-Up Test (for 60 sec.), quantity of times [27].

Test 5. Seated Forward Bend, cm [28].

Test exercises to identify special physical fitness (SPF) are the following:

Test 6. Gymnast bridge (modified). Equipment: gymnastic mat. Description: The student performs the Gymnast bridge, then shortens the distance between the heels and fingertips.

This position is held for 2 sec. The test is repeated twice. The test result is the distance between the heels and the fingertips. The best of the two attempts is counted. Note: watch the wrists and the body balance. If the participant does not fully straighten the elbows, the exercise is a failure.

Test 7. Right split. Equipment: gymnastic bar (20 cm height). Description: starting position it the third position [29]; the right foot bears by the heel on the Gymnastic bar; the toe is pointed. The exercise Right split is performed at the command "Go". The student bears by his palms on the floor, the body leans forward.

The lower position is fixed for 2 sec. The test is repeated twice.

The test result is the best distance between the floor and the lower point of the pelvis (coccyx).

Note: the exercise should be performed smoothly; both legs should form one line. If the participant bends his legs at the knees, the attempt is a failure.

Test 8. Side split. Equipment: gymnastic bar (20 cm height). Description: starting position is the first position [29], the right foot bears by the heel on the Gymnastic bar; the toe is pointed. The exercise Side split is performed at the command "Go". The student bears by his palms on the floor, the body leans forward.

The lower position is fixed for 2 sec. The test is repeated twice.

The test result is the best distance between the floor and the lower point of the pelvis (coccyx).

Note: the exercise should be performed smoothly; both legs should form one line. If the participant bends his legs at the knees, the attempt is a failure.

Test 9. *Sissonne fermée*. Equipment: non-skid surface with a line and marking in centimeters. Description: the participant stand at the line in the fifth position [29]; right foot in front.

At the command "Go" student:

- opens his arms in the *allongé* (back straight);
- squats;
- jumps forward (perform a swing with the right foot forward).

After the jump, the student returns to the fifth position [29]; in *plié* on both feet. The test result is a jump distance in centimeters, the best of the two attempts. Note: if during the jump the participant bends his knees, does not point the toe, the attempt is a failure.

Test 10. Jumps on the spot with bent legs. Equipment: non-skid surface with a mark, stopwatch. Description: The participant stands at the mark in the sixth position [29], hands on the waist. The student jumps up at the command "Go" (both legs are bent, his back is kept straight).

The test result is the number of jumps per minute. Note: In jumping, the heels should touch the buttocks and the toes should be pointed. If the participant leaves the mark, the attempt is a failure.

Test 11. Balance maintaining in the "arabesque".

Equipment: non-skid surface with the line, stopwatch. Description:

- the participant stands at the line,
- right leg in the turnout position,
- flat left foot leads back to the toe,
- The arms open into the first position "arabesque" (right foot forward and left foot sideways in the *allongé*).

The student raises the left leg in the turnout position on 90 degrees at the command "Go". The position "arabesque" is kept as long as possible. The test result is the number of sec of keeping the position without body vibrations. Note: both legs should be pointed at the knees, the toes pointed as much as possible, back is straight. The attempt is a failure if the participant puts down his left leg earlier than in 10 sec.

Statistical analysis. We used the statistical analysis program SPSS 20. For each variable was calculated: $\bar{X}$ – arithmetic mean; s – the standard deviation; Δx – the marginal sampling error for the mean; t – Student's criterion; p – the significance level. The significance of differences in groups was estimated using parametric indicators (Student's criterion) and non-parametric indicators (Wilkinson-Mann-Whitney criterion, Rosenbaum criterion).

Results

It was determined low indicators in the Seated Forward Bend test (Test 5) in students at the beginning of 1 year

of study. It was determined the average level of indicators of special dorsal spine mobility. The highest indicator in females was in test 7 ($9.4 \text{ cm} \pm 2.16$). At the beginning of the study, no students with a high level of general and special physical fitness were identified. The lowest results are observed in the indicators of strength training, dorsal spine mobility, and agility. Significantly better indicators were found in explosive strength in males and females (Test 2); strength endurance in males (Test 9). The results of the general physical fitness of students in 1 and 3 years of study under the influence of professional training disciplines are presented in Table 1.

Significant changes in the dynamics of females' indicators took place in the following tests: females – test 4 ($t = 5.84, z = 0$), test 3 ($z = 3$) and test 5 ($z = 1$). The results in tests 1, 2, 3 (Table 1, females) were on downtrend.

The results of males' testing indicate significant changes in test 4 ($t = -2.62, z = 0$) and test 3 ($t = -4.82, z = 0$). The results of test 5 also have positive changes. The results of tests 1, 2 are on uptrend insignificantly (Table 1).

The special physical fitness of students was determined by testing special exercises. The dynamics of changes in indicators in special tests for 1 and 3 courses are presented

in Table 2.

The females had a significant change in all indicators of selected tests of special physical training (Table 2), as follows: in test 6 ($t = 4.26, z = 0$), in test 7 ($t = 2.57, z = 0$), in test 8 ($t = 2.03, z = 0$), in test 9 ($t = -4.57, z = 0$), in test 10 ($t = -2.72, z = 1$), in test 11 ($t = -2.05, z = 0$).

In males the probable changes in results of special physical exercises testing are observed as follows: test 7 ($t = 2.03, z = 0$), test 8 ($z = 0$), test 11 (tab. 2). Test 9 ($z = 0$) males perform at the average level (Table 2).

There was an increase in the average values of explosive strength and strength endurance: males - test 3 ($z = 0$) and test 10; females - test 10. Both males and females have increased coordination level (test 11). The positive dynamics of the Seated Forward Bend test (females, males) indicates the effectiveness of the special dorsal spine mobility program.

The results of the study showed significant changes in the indicators of students' special physical fitness. The level of certain indicators of general physical fitness in females is on a downtrend (test 1, 2, 3).

Discussion

Our study was aimed at determining the level of physical qualities of students under the influence of

Table 1. The dynamics in indicators of students' general physical fitness

Tests	Females (n = 10)			Males (n = 5)		
	Beginning of the study	End of the study	p	Beginning of the study	End of the study	p
1. 4x9 m Shuttle test, sec.	10.87±0.17	10.88±0.25	0.929	9.53±0.20	9.45±0.26	0,59
2. Standing Long Jump Test (Broad Jump), cm	180.40±2.30	179.90±2.66	0.495	216.75±4.89	222.00±1.78	0,23
3. Vertical Jump Test (Sargent Jump), cm.	39.20±1.28	38.00±1.58	0.585	50.25±0.63	55.00±0.91*	0,04
4. President's Challenge Curl-Up Test (for 60 sec), quantity of times	37.20±1.28	46.80±1.03*	0.000	53.25±1.38	60.50±2.40*	0,01
5. Seated Forward Bend, cm	9.50±1.27	11.20±1.24	0.001	6.00±2.31	9.75±2.17	0,00

* - differences are significant according to Student's criterion.

Table 2. The dynamics in indicators of students' special physical fitness

Tests	Females (n = 10)			Males (n = 5)		
	Beginning of the study	End of the study	p	Beginning of the study	End of the study	p
6. Gymnast bridge, cm	56.10±0.77	51.10±0.89*	0.000	57.00±3.49	53.75±3.57	0.01
7. Right split, cm	9.40±1.15	5.20±1.16*	0.000	14.25±1.44	10.75±0.95*	0.01
8. Side split, cm	14.00±1.70	9.30±1.56*	0.000	16.00±3.34	12.50±2.84	0.01
9. Sissonne fermée, cm	54.60±0.99	60.60±0.86*	0.000	53.75±1.49	56.75±0.85	0.13
10. Jumps on the spot with bent legs, quantity of times for 60 sec	79.60±1.54	60.60±1.87*	0.000	92.75±2.14	97.25±3.64	0.08
11. Balance maintaining in «arabesque», sec	38.60±1.79	44.00±1.93*	0.000	41.50±2.53	45.75±3.25	0.02

* - differences are significant according to Student's criterion

professional training disciplines. The obtained results confirm the conclusions of Shchur [5] about the physical condition level of the art specialties students. The results correspond to the average level.

During the two years of study, females showed a downtrend of the results in tests 1, 2, 3. The attention should be paid to the development of speed and strength for the harmonious physical condition of females. We could partially agree with the research of Marinchuk [7] on the peculiarities of physical fitness of the art specialties students. The author emphasizes the decrease of these indicators during training. He has also justified the need to develop strength endurance and dorsal spine mobility.

We agree with the results of Chuba [14] and Wang Yang et al. [30] studies. We emphasized that the professional training of future choreography teachers for various types of work (organizational and creative, performance, choreography, teaching) creates opportunities for students to master important professional competencies.

The significant place in the professional training of future choreography teachers is given to technical training. The technical training level directly depends on the level of physical fitness. Mastering the technique of complex movements (medium and large jumps, pirouettes, trick elements of dance) is impossible without the physical ability to perform them.

High and difficult jumps (*sissonne fermée in I, II, III arabesque, pas ballone, pas de chat, grand pas assemble en tournant*) require: vigorous grips of the hands and lower part of the working leg; swinging movements of the torso, hands, working leg; clarity of head turns in the corresponding positions. Such jumps should be coordinated according to the tempo and rhythm of the musical accompaniment.

Dexterity and coordination of movements are extremely important for folk dance. The majority of practicing trainers consider the development of dexterity and coordination in the complex [17, 31, 32]. We agree with the opinion of experts that the dexterity development is achieved by: the use of complex coordination exercises and exercises with elements of suddenness; performing exercises based on sound or visual signals that correspond to a change in the direction of movement or a change in the movement itself. To be agile and coordinated in choreography is to meet the following requirements: to quickly master new movements of different types of dance and improve them; change movements quickly enough in accordance with the proposed circumstances; master complex coordination exercises in different types and styles of dance; perform movements accurately and correctly.

The program for the students' special physical fitness development in the methodology of teaching choreographic disciplines provides the abovementioned components. The exercise near the bar of classical and folk-stage dance is composed in such a way that the muscles are gradually included in the work: from the ankle (*demi and grand plié, battement tendu, battement tendu jeté*) to the hip joints (*rond de jamb par terre, battement*

foundu, battement frappé, adajio, grand battement jeté). This is a well-known principle in learning - from simple to complex.

Our study confirms the effectiveness of the special dorsal spine mobility development. Insufficient flexibility in the hip joint leads to a decrease in turnout in the knee joint and the ankle. This leads to complications in performing jumps and squats. Limited dorsal spine mobility does not allow you to perform movements properly with maximum amplitude: different types of port de bras, arabesque. The active dorsal spine mobility becomes especially important in the process of choreography training. The active dorsal spine mobility is realized in performing specific dance movements and exercises with high amplitude. Passive and active stretching exercises are a mandatory part of the student dorsal spine mobility program. Such exercises provide the required freedom level of the dancer's body. They prevent professional injuries to muscles and joints. These exercises must be included in the warm-up and the final stage of the choreography training.

The main means of the plastic language of any dance is a pose. The training aplomb in a pose is a complex and time-consuming process. This process requires the dancer to concentrate on the following analyzers: vestibular, motor, visual. We used test 11 to determine the level of aplomb in students.

The development of strength endurance is achieved by performing jumps on the spot with straight and/or bent legs; running on the spot at a fast pace; alternation - jumping with walking, jumping with a load, jumping rope. The pace should be close to the real concert and competition program. More approaches increase the number of repetitions. This leads to significant fatigue and the need to regulate breathing, stress, and rest.

In the case of reductions in-classroom training for future choreography teachers, more attention should be paid to the independent work of students. A component of such work is the increasing level of physical fitness: performing art tasks; independent compilation and demonstration of technical exercises; performance of art projects with group's students. The student must constantly improve their physical fitness and improve the appropriate functional abilities to perform complex dance movements (classical dance, folk-stage dance, modern dance).

The specifics of students' professional training (future teachers) determines the use of the following forms of the educational process organization: practical and individual training; a set of externship in the specialty. The forms of extracurricular work of students should be as follows: participation in concerts, competitions, festivals. This is an incentive and encouragement to develop physical qualities and self-improvement. We agree with other authors [12, 33] that such an active form of professional training provides consolidation and integration of formed theoretical knowledge; acquired practical skills and abilities in the methodology of teaching choreographic disciplines.

Conclusions

It is recommended to constantly monitor future choreographers' physical fitness. This makes it possible to determine the effectiveness of the complex influence of professional disciplines on the students' physical fitness. Disciplines of professional training are the basis for acquiring the professional skills of dancers. This will help to improve the training program on time.

The exclusion of the discipline "Physical Education" from the training programs of choreography teachers requires appropriate compensation for specific physical activity. These can be students' independent classes in physical education. It also requires the correction of special training programs that include physical activity.

Conflict of interest

The authors declare no conflict of interest.

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Differences in kinematic parameters between male and female hammer throw finalists of the World Championship in Daegu in 2011

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Abstract

Purpose: Hammer throwing is the most complex athletic throwing discipline with rotational trajectory and strong effect of several different forces that try to disable the projected throwing trajectory. Kinematic parameters are an important segment in the analysis of athletic disciplines, including hammer throw. They are an indicator of influence and often a difference between competitors of different or the same rank of the competition. The aim of the study was to determine the spatial and temporal differences of kinematic parameters between male and female elite hammers.

Material: The study was conducted on sample of 16 Daegu World Championship finalists in 2011, to analyse differences in kinematic parameters between male and female throwers hammer. To obtain the required results, t-test for small independent samples was applied.

Results: The data obtained in the study were given as Mean and Standard deviation. Statistically significant differences between male and female finalists were confirmed in the rate of ejection ($t=3.684$; $p<0.004$) and the speed of the fourth turn ($t=4.396$; $p<0.002$). The male finalists achieved an average ejection velocity of 27.91m/s and the female finalists 27.17m/s, with an average turn speed of 4.67m/s (male) and 4.03m/s (female).

Conclusions: The research has shown that significant differences were made between male and female finalists in Daegu in 2011. The causes of differences can be found in length of training, different training process, technical mastery, competitor experience, morphological profile, motor and anatomical structures, movement technique and biomechanical parameters, which were not taken into the research.

Keywords: World Championship, kinematic parameters, hammer throw, differences.

Introduction

Throws are movements that shift certain weights over some distance, affect muscle mass, increase the strength of the entire body, and especially the muscles of the arms, shoulder girdle and the entire body. They also, to certain extent, develop agility and speed, and they are part of phylogenetic form of movement that, over time, with continuous training process, translates into forms of various ontogenetic forms, the so-called athletic throws. One such ontogenetic form is hammer throw. The main objective is to throw the hammer as far as possible in accordance with the rules of the competition. From historical distance, hammer throwing is related to the Celtic tradition, where originally hammer with wooden handle was thrown at competitions. This hammer throw has continued to this day in popular contests among the Irish and the Scots. Then rotate around their vertical shafts like today's. By 1878, the hammer was thrown quite primitively, firmly standing from the line drawn and since then from a circle 2,135m in diameter. It is mostly thrown from the standing point, with no turns, and later with one or two turns in circular swing and throwing out. The turn is made on the heel, and after ejection step forward is usual, while the length of the shot is measured from the place where the ejector stops after the ejection. After the dominance of American competitors (Totell,

Callaghan, Quinn), in the thirties began the dominance of European throwers. Everyone is trying to find the best movement technique for successful shot. Particularly standing out were German (Hein, Blask) who introduced the so-called German version of hammer throw. This variant is modified by Comstok, Nemet, and later Russian Krivososov, Bonadrchuk, Spiridonov introducing new so-called Russian version of hammer throw with the aim of increasing the radius of the spin in hammer system [1].

Generally, in uneducated subjects, the opinion is that because of their constitution, is less effective in displaying motor skills, which is wrong. They have high level of development and manifestation of motor skills during motor movement [2]. In addition to motor skills, an important place is occupied by the body composition of the thrower. According to Ugarković [3], male and female throwers are dominated by muscle mass (53-56%), bone mass (18-22%) and fat (15-19%). Based on these parameters, it can be concluded that in the thrower the primary is mesomorphic with the endomorphic and ectomorphic component, according to which the hammer throwers correspond to the meso-endomorphic somatotype (3.75-5.50-2.25). Pavlović, Radinović, & Janković [4], Pavlović, Raković, Radić, Simeonov, & Piršl [5] consider that throwers have greater amount of muscle mass compared to other athletes and are closest to the mesomorphic type according to Sheldon's classification. They have lower body height (190cm) and

larger body weight (113kg) which is positively correlated with performance. From motor point of view, all athletic throws, including hammer throws, are initiated by the explosive activation of agonist muscles, followed by period of relaxation, and end with deceleration period due to the action of the antagonist muscles or the passive stretching of connective tissue with an integrated involvement of particular motor skills (static, repetitive and explosive power, flexibility, balance, anaerobic potential). Hammer throw is characterized by the maximum speed of movement being achieved through rotations around the vertical axis in the sagittal plane to the moment of ejection, which requires a kinaesthetic feel, high degree of motor skills, above all speed power, coordination of movement, excellent orientation during the execution of turns and sense of rhythm. Top throwers perform three or four turns (the official world record of Soviet thrower Yuriy Sedikh is 86.74m at the 19th European Championship in Stuttgart and was achieved with three turns) [1]. It was thought that four turns were performed by lower and more technically trained (faster) throwers and three turns by more powerful throwers. However, today, both variants are common with all throwers, with four turns and even five turns being more common. At turns, the thrower and the hammer do not only rotate around the vertical axis, but they also move in the direction of the throw as the speed of rotation increases [6, 7]. During the turn, large centrifugal force develops, transferring to the thrower, trying to knock them down. In order to counteract the fall, the thrower tilts to the opposite side of the hammer (the so-called counterweight). The size of the pitch of the thrower's body to the opposite side of the hammer depends on the thrower's own weight, physical fitness and technical skill. The greater the weight of the thrower, as well as his strength, the lower the incline. Maintaining the vertical position of the body while turning is almost impossible, but it should be pursued, because if the axis of rotation is left unchanged, the hammer rotation lever increases, and ultimately the flight distance of the device increases too [8]. Identical to other throwing disciplines, hammer flight distance depends on the initial flight velocity, the angle of ejection, and the height of the ejection point [9], of which speed has proven to be the most important [10, 11]. According to Maroński [12], an increase in ejection velocity dramatically improves the range of any projectile throw, while Bowerman, Freeman, & Vern Gambetta [13] believe that an increase in velocity by 5% can increase the result by 7 meters while changing the angle by 5% alters the length for only 60cm. From a biomechanical point of view, it is primary for hammer throwers to communicate as much speed (through turns) as possible within a short time interval within the limits of the support surface [1], despite the effect of gravitational force.

In addition to the influence of the primary factors in the resultant success, gravitational, centrifugal and Coriolis forces act as well [14]. Using computer modelling for typical ejection heights and optimum hammer ejection angles, the impact of Earth rotation on the hammer throw and collision distance with air currents, air pressure,

temperature, altitude, and earth slope, presented practical maps for technique correction to achieve results at different latitudes and/or different release directions can be corrected by a formula that incorporates the effect of earth's rotation. The hammer movement system in space includes phenomena that affect the functional flow of the ultimate speed of the device [15]. The spatial trajectory of the hammer head and the corresponding anthropometric points are evaluated from the standpoint of single turns, double and single support and ejection phases, studying the tangential and acceleration components as well as the forces acting on the device. Positive factors have been found to cause an increase in the speed of the hammer head, including several factors (Strong foot action, with the feet constantly rotating and never held in a static double-pivot position; two turns of length; Rotation of the torso in front of the pelvis, with displacement of the centre of the shoulder line connecting the right hip joint; rotation of the shoulder axis in front of the hammer axis; vertical lifting of the hip joints in the direction of vertical movement of the hammer and hammer head; obtuse angle between the shoulder axis and the hammer, with the highest possible position of the device in the range of 1.60 to 2.00 meters at the beginning of the ejection phase. Dapena, & Mc Donald [16], using three-dimensional cinematography, recorded the angular momentum of elite throwers, their trajectory, and vector accelerations.

They proved that the trajectory of the angular momentum vector, the incline of the body and the height of the hammer plane with respect to the mass system of the thrower are interrelated. Some throwers hold the hammer handle high (the body tilts back in all turns), while other throwers hold the hammer handle low (the body tilts forward in the initial turns), so in later turns the hammer handle rises as the body tilts back. They also suggested some theories to explain why athletes who lean forward in the first turn, in the back of the throw, lean back. Dapena, Gutiérrez-Dávila, Soto, & Rojas-Ruiz [17] analyse the resultant hammer throw performance as consequence of neutralizing air flow resistance, assuming the centre of mass of the hammer coincides with the centre of the ball. To calculate kinematic parameters in hammer ejection, they use three-dimensional throwing data for male and female competitors using a mathematical model simulation. The distance provided for the vacuum and centre of gravity of the hammer ball is approximately 4.30m longer than the official throwing distance for men and 8.80m longer for women. Predictions of use of the right centre of mass of the hammer reduced the deviations for men ($2.39 \pm 2.58\text{m}$) and women ($5.28 \pm 2.88\text{m}$), while the predictions of the action of air resistance and the true centre of mass of the hammer further reduced the deviations for the men ($-0.46 \pm 2.63\text{m}$) and women's ($1.16 \pm 2.31\text{m}$). Half of the loss of distance 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. It is an indisputable fact that increasing the force of the hammer wire when turning is crucial for throwing distance. Brice, Ness, Rosemond,

Lyons, & Davis [18] analysed the top five hammer throws and calculated the force acting on the hammer head from Newton's second law of motion, and then compared it with the force measured by stress apparatus. The results showed that the qualitative time dependence of the two forces was essentially the same, while the quantitative average difference between the measured and calculated forces over the five throws was 76N, corresponding to difference of 3.8% for the hammer wire force of 2000N. Also, Brice, Ness, & Rosemond [19] on sample of male and female throwers, analysed the relationship of force and linear velocity of the hammer wire when throwing, and identified the influence of the magnitude and direction of the force on the fluctuation of the hammer speed. The results showed strong correlation between the decrease in linear velocity and the hammer wire force (normalized to its weight). A strong correlation was also found between the angle at which the hammer force lags behind in its rotation radius to its maximum (when the tangential force is most negative) and the magnitude of the hammer speed decrease. All top hammer throwers are known to have good anatomical and physiological muscle structure that allows for top-notch technique execution.

The study by Terzis, Spengos, Kavouras, Manta, & Georgiadis [20] confirmed that the efficiency of hammer throwing is highly correlated with the athlete's lean body mass and higher bone mineral density. They have also proven that the percentage of type IIA muscle fibre surface is over 66% with more than 8000 fibres in the muscle structure. According to Ojanen, Rauhala, & Häkkinen [21] maximum power, explosive power, muscle thickness, and power characteristics decline with aging, and with throwers who have been actively practicing power and throwing for decades. However, with top athletes, the maximum strength, muscle mass as well as the explosive force of the upper and lower extremities appear to be at significantly higher levels than those recorded for men of the same age. A group of Brazilian authors [9] analysed differences in kinematic parameters (angle, velocity, ejection height, velocity curve as a function of time) between Brazilian and international throwers, starting with the 3D trajectory of the hammer head. The results showed the resultant inferiority of Brazilian throwers with respect to international throwers, in the ejection velocity (average 24.59m/s male and 23.59m/s female), international (average 29.60m/s male and 28.89m/s female). The velocity curves as function of the time of the international throwers compared to the Brazilian sample show that accelerations are higher and deceleration is smaller during the turn. The success in hammer throw depends on training, years of experience, training volume [22]. A survey of American throwers examined the parameters that contributed most to distance in hammer throwing. Multiple regression analysis for the personal hammer throw record provided significant model ($r=0.811$, $p\leq 0.001$) with predictors (number of throws per year, number of hammer throws, back squat and type of hammer technique). The model explained more than 65% of the discrepancy in hammer technique among

respondents, thus providing quantitative information for coaches and athletes involved in this throwing discipline. Also different anthropometric differences between the genders affect the technique and the end result of hammer throw. Konz, & Hunter [23] on a sample of 16 male and female throwers of the 2003 World Athletics Finals and 13 male and female throwers from the USA in 2003 conduct research to determine differences in the technique of throwing between the genders. The results revealed that athlete mass, athlete height; ejection rate, some temporal components, and centripetal force were different between the two genders. Panoutsakopoulos, Vujkov, & Obradović [24] on a sample of male and female competitors investigated the relationship between hammer throw duration and distance of three and four turns, and examined the relationship between hammer throw duration and hammer throw performance by two-line Pearson correlations. The results showed that there was a high and strong correlation between throwing duration and throwing distance for 4-turn throwers ($r=-.83$; $p<0.01$) and 3 turn throwers ($r=-.96$; $p<0.01$). Most throwers during the technique of execution, spent more time in single-support than in double-support. It was concluded that the greater the throwing distance, the shorter the total turn duration, i.e. in the inverse relationship.

The main goal of this research was defined on the basis of the insight and review of the previous research and based on the previous research results. The aim of the current research is to analyse and determine statistically significant differences in kinematic parameters between male and female hammer throwers in the 2011 Daegu World Athletics Championship finals.

Material and Methods

Participants

The sample included 16 top Hammer throwers (8 male and 8 female) who competed in the 2011 World Championship finals in Daegu, average result male 79,06m and female 73,80m.

Procedure

All data of kinematic parameters are taken from the Scientific Research Project Biomechanical Analyses at the 13 IAAF World Championship, Daegu, 2011. Variables were identified for estimating of biomechanical parameters in Hammer throwers (Table 1).

1. Starting velocity (m/s)
2. Velocity of release (m/s)
3. Angle of Release ($^{\circ}$)
4. Increase of Velocity (m/s):
 - a) Turn 1 (m/s);
 - b) Turn 2 (m/s);
 - c) Turn 3 (m/s),
 - d) Turn 4 (m/s)

Statistical Analysis

The data obtained in the study were given as mean and standard deviation. Independent T-test for small samples was used, and the significance level was accepted as $p<0.001$. Statistica 10.0 program was used in the statistical analysis of the study.

Table 1. The Kinematic Parameters of Male and Female Finalists WCh, Daegu 2011. [37]

Male	Distance (m)	Starting Velocity (m/s)	Increase Velocity (m/s)				Velocity of Release (m/s)	Angle of Release (°)
			Turn 1 (m/s)	Turn 2 (m/s)	Turn 3 (m/s)	Turn 4 (m/s)		
Murofushi	81.24	16.7	3.4	2.4	1.3	4.6	28.3	41.4
Pars	81.18	18.1	2.9	1.6	1.0	4.6	28.2	44.1
Kozmus	79.39	16.4	3.5	2.2	1.2	4.7	28.1	39.0
Esser	79.12	16.3	3.8	1.9	0.9	5.0	27.9	41.1
Kryvitski	78.53	16.1	3.5	2.3	1.4	4.7	27.9	39.1
Ikonnikov	78.37	15.9	3.7	2.4	1.2	4.6	27.7	44.1
Ziolkowski	77.64	16.4	3.3	2.3	1.3	4.5	27.8	38.9
Vizzoni	77.04	17.6	2.6	2.3	5.0	-	27.4	43.9
Mean	79.06	16.69	3.33	2.12	1.66	4.67	27.91	41.5

Female	Distance (m)	Starting Velocity (m/s)	Increase Velocity (m/s)				Velocity of Release (m/s)	Angle of Release (°)
			Turn 1 (m/s)	Turn 2 (m/s)	Turn 3 (m/s)	Turn 4 (m/s)		
Lysenko	77.13	16.4	4.5	2.3	0.8	3.8	27.8	43.1
Heidler	76.06	18.4	2.6	1.7	1.0	3.9	27.6	40.1
Zhang	75.03	17.9	3.1	1.9	1.1	3.4	27.4	42.6
Moreno	74.48	14.4	4.0	2.9	1.6	4.4	27.3	41.1
Wlodarczyk	73.56	15.5	3.7	2.6	1.3	4.4	27.4	36.6
Perie	72.04	16.2	2.9	2.4	0.9	4.4	26.8	40.3
Klaas	71.89	17.5	2.8	1.8	0.8	3.9	26.7	41.9
Marghieva	70.27	13.6	5.2	2.5	1.1	4.0	25.8	43.1
Mean	73.80	16.2	3.6	2.26	1.07	4.02	27.1	41.1

Results

Inspection of Table 2 revealed quantitative differences in all measured kinematic parameters between male and female finalists. Men achieved higher average starting speed (16.69m/s), they were faster in third (1.66m/s) and fourth turn (4.67m/s), while women had (3.60m/s) in first and (2.26m/s) in second turn. Both samples exhibited fluctuations in velocity increment and almost identical ejection angle. (Table 2). Statistically significant differences were observed only in the parameters of ejection rates ($T=3.684$; $p<0.004$) and speed in the fourth turn ($T=4.396$; $p<0.002$) in favour of male competitors. The average ejection velocity of the male finalists at Daegu is (27.91m/s), which is 0.73m/s faster than the female finalists, while the angle of ejection is minimal (Table 1, 2). The highest ejection velocity was achieved by the first-ranked Murofushi (28.3m/s), with an ejection angle of 41.4° and starting velocity of 16.7m/s. The individual starting speed of the male finalists ranged from 15.9m/s (Ikonnikov) to 18.1m/s (Pars) and the ejection speed from 27.4m/s (Vizzoni) to 28.3m/s (first place Murofushi). The average initial velocity of ejaculation (starting velocity) of males was 16.69m/s and at ejection it was 27.91m/s (almost 28m/s). It follows that during four turns the speed increased by 11.22m/s with considerable oscillations in the speed of turn (3.33-2.12-1.66-4.67m/s). The hammer was thrown with an average ejection angle of 41.5°, ranging from minimum of 38.9° (Ziolkowski)

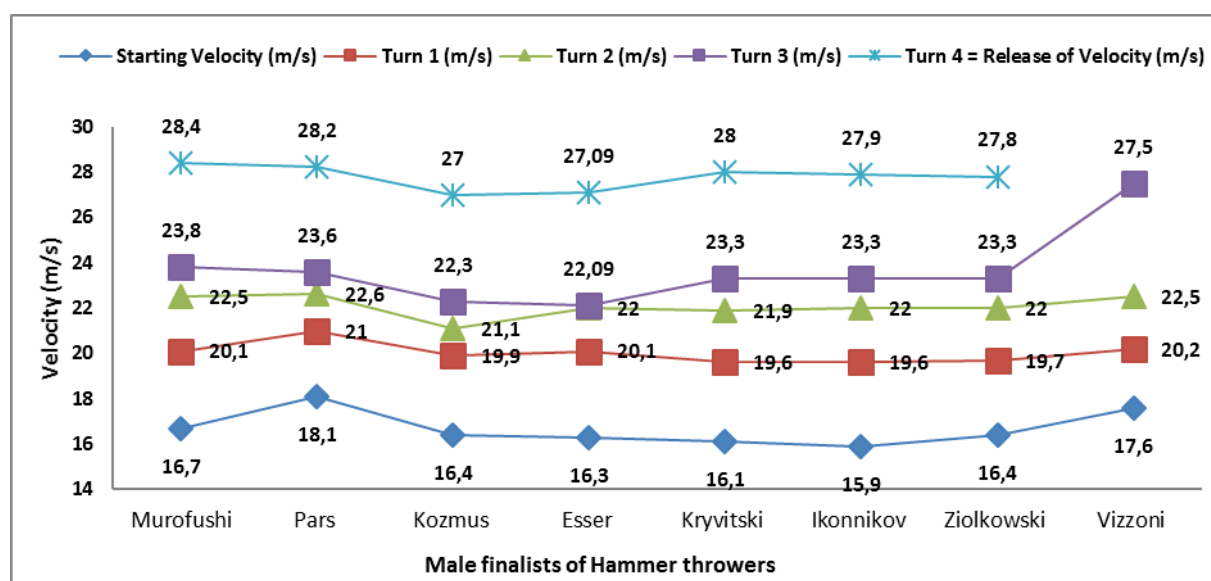
to maximum of 43.9° (Vizzoni). (Table 1; Figure 1, 3). It can be concluded that the speed increased with the number of turns, which is the goal of every hammer thrower, to maximize the speed at the moment of ejection. In addition to the statistical difference in ejection rate between finalists, the difference was made in the speed of execution of the last fourth turn, where the male finalists were faster by 64ms (Table 1, 2; Figure 3).

When we talk about female throwers, Lysenko threw the hammer with the highest starting speed (27.8m/s) and slightly higher recoil angle of 43° at starting speed of 16.4m/s. Female throwers achieved lower starting speed than male finalists, ranging from 13.6m/s (Marghieva) to 18.4m/s (Heidler) with tendency to grow in the last turn. Also, women were inferior to the individual results of the ejection velocity from 26.4m/s (Marghieva) to 27.8m/s (Lysenko) and the average initial velocity of 10.9m/s (Table 2, Figures 2 and 3). The average initial velocity of ejaculation of females is 16.20m/s and at ejection is 27.10m/s. Over the course of four turns, this speed increased by 10.90m/s with considerable oscillations in the speed of rotation (3.6-2.26-1.07-4.02m/s). The average ejection angle is 41.1°, with maximum of 43.1° (Maghieva, Lysenko) and minimum of 36.6° (Wlodarczyk). Marghi was last placed, with the lowest starting speed (13.6m/s) and the breaking speed (25.8m/s), unlike the male finalists, where the first-ranked Murofushi had the lower speed than the two competitors (16.7m/s),

Table 2. The differences in kinematic parameters between male and female Hammer throwers

The kinematic parameters	Gender	Mean±St.Dev.	t-value	p- value (2-sided)	95% CI
Starting Velocity (m/s)	Male	16.69±0.776	0.687	0.508	-0.955 to 1.855
	Female	16.24±1.688			
Increase velocity (m/s)	Turn 1 (m/s)	Male	-0.739	0.477	-1,024 to 0,499
		Female			
	Turn 2 (m/s)	Male	-0.486	0.635	-0,473 to 0,298
		Female			
	Turn 3 (m/s)	Male	1.200	0.267	-0,463 to 1,638
		Female			
	Turn 4 (m/s)	Male	4.396	0.002**	0,329 to 0,964
		Female			
Release of velocity (m/s)	Male	27.91±0.290	3.684	0.004**	0.308 to 1.167
	Female	27.17±0.486			
Angle of release (°)	Male	41.45±2.336	0.311	0.760	-2.065 to 2.765
	Female	41.10±2.164			

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


Figure 1. Distribution of male results in kinematics parameters

but still managed to achieve the highest ejection rate (Table 1; Figures 2, 3). It can be concluded that he had good maximum speed gain through four turns and good movement technique (11.6m/s).

Discussion

The main objective of the study was to determine the differences in kinematic parameters between male and female finalists in the 2011 World Athletic Championship in Daegu. Results were obtained confirming the significant differences between the genders, which is the main result of the research. The question arises as to the cause of such results?

First of all, hammer throw competition is considered to be one of the most complex throwing competitions in

terms of technique and difficulty encountered in training [25]. It is complex movement that requires the expression of different forces and the harmony of the movements of the competitors [2], and depends on the type of training, years of experience and volume of training [22]. Coordination is the most complex technique of the throwing discipline, so high results at the international level require continuous improvement. The technique of movement depends on achieving the maximum speed of the hammer through the turns up to the moment of device ejection [26, 27], the angle and height of the ejection [13]. The technique integrates rotational motion in which there is reciprocal action of the thrower-hammer system, which always rotates about the shaft passing between the centre of gravity of the thrower body and the hammer, as well

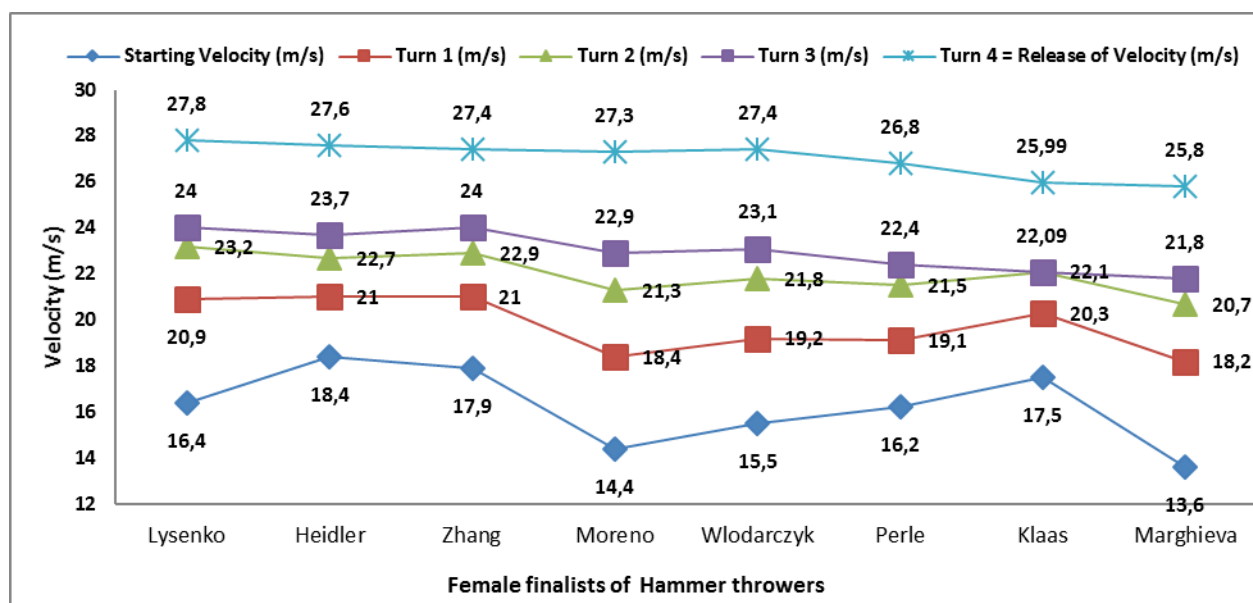


Figure 2. Distribution of female results in kinematics parameters

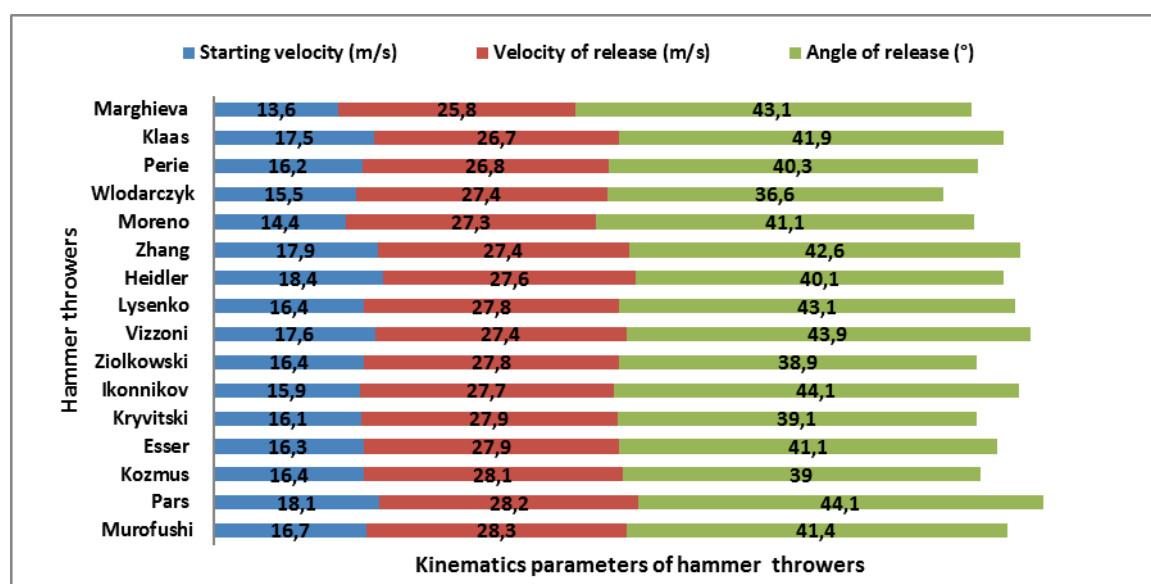


Figure 3. Distribution of individual results competitors

as through the support and the surface. Each movement begins with the initial swinging of the thrower, creating the conditions for entry into the first turn, allowing the thrower to reach the necessary rhythm and good concentration, which is important for the further stages of the technique. The number of turns performed depends primarily on the training of the thrower, his anatomical and physiological structures, and motor skills [20]. This is followed by sweeps, where the competitor rotates with the hammer around the vertical axis. During the hammer waving, the initial turning speed (12-16m/s) is announced and the common centre of gravity of the system (thrower-hammer) must be within the limits of the support surface [1,7]. The results of the current survey are in accordance with the above, where the average starting speed ranges from 16.2m/s (women) to 16.7m/s (men).

In the hammer override phase, the movement of

the launcher is directed to achieve the highest speed of rotation [23,24], where the launcher and the hammer form unique system that performs complex rotational motion by rotating the launcher around its vertical axis, while moving in a sagittal plane, from the last part of the circle towards the front maximum speed, i.e. achieve maximum speed and act on the device in the ejection phase [11]. If the coordination of the thrower and thus the turns, is better, the speed of each subsequent turn is higher and the fluctuation of the speed is recorded. As its velocity increases, the centrifugal force (2900-4000N) increases, affecting the balance of the competitor, seeking to dislodge it from the imaginary path which counteracts the action of strong centrifugal force by tilting the body in backward compensatory movements of the leg joints, bending the knees lowering the centre of gravity of the body [1, 6, 7, 8]. In order to make the swing as large as possible, the

thrower makes certain twists with soft movements in the joints of the spine and hips. When the hammer is moving away from the body, the thrower moves the pelvic part of the body opposite to the device, accelerating the hammer, performing a second pre-swing, creating the preconditions for the start of the second or third swing [1, 6, 9]. During the rotation, the hammer speed gradually increases and reaches velocity close to 28m/s at the moment of ejection [23] while the ideal ejection angle is 40°, although some top throwers throw at an angle of 38° to 40° [13]. However, some authors believe that the angle depends on the height of the athlete and ranges from 42 to 44° [7, 8, 28], which is contrary to the results of this research. The average ejection angle of finalists in Daegu is 41° with individual higher or lower competitor values, which is consistent with the allegations [13]. Štuhec, Vertič, & Čoh [11] found the largest differences in ejection velocity (2.6m/s) in the analysis between Y. Sedikh and P. Kozmus, while the ejection angle and height were almost identical, which is similar to the results of this study (Table 2, Figures 1-3).

Hammer throw is characterized by complex spatial and temporal structure, with the aim of achieving maximum movement speed through two or three movements and moving in 3, 4 or 5 turns, moving linearly through the centre of the throwing circle. Such movement further complicates changes in the spatial orientation of planes that define the trajectory of the hammer movement in each turn [29]. Each thrower in one turn goes through two clearly differentiated periods: double-backing (entry of the thrower into the turn) and single-backing (exit of the thrower from the turn). It is common opinion that the hammer acceleration is achieved in the double-backing contact phase (the hammer pull force is directed downwards and forwards to build the stability of the thrower and to achieve greater speed of movement) rather than the one-backing (the hammer pull force is very strong and is counteracted by the deflection of the hull which is the opposite of the hammer position). Both phases are of very short duration (0.20-0.26s), which decrease as one goes from the first to the fourth turn. Also, at turns, the distance between the feet decreases and speed increases, from the initial 16m/s to over 28m/s at the moment of ejection, as confirmed by the results of this study (Table 1, Figure 3). Based on this theory, some coaches [30, 31] have tried to extend the double-backed support phase and have largely contributed to the excellent results of Soviet throwers in recent decades. The theory is proved by the marked fluctuation in the speed of the hammer in each double-backing support and noticeable decrease in the single-backing support.

However, Dapena [16, 28] questioned this theory, so he proved that it is possible to increase the speed even in a single-backing support. He believes that the impact of the thrower on the hammer speed cannot be negative, even when the thrower pulls the hammer towards the body, because it comes from the highest point of the trajectory. Exactly in our sample there is a fluctuation in speed through turns, where female finalists recorded slightly higher average speeds in the first and second turns

(Turn 1=3.6m/s; Turn 2=2.26m/s) than the male (Turn 1=3.33m/s; Turn 2=2.12m/s) and the third and fourth turns are dominated by male finalists (Turn 3=1.66m/s; Turn 4=4.67m/s), with this that there were statistically significant differences between the finalists in the fourth turn (Table 2). According to some authors [1, 7, 8], the turning of the hammer begins when it is on the right side, below shoulder height. At the moment of passing over the arch of the left foot, the velocity of the hammer head is the highest and therefore the strongest centrifugal force, so the incline of the thrower is necessary for balance. When entering the first turn, the shoulders and hips are parallel, however, when exiting the turn and moving into the single-backing period, the hips move faster, overtaking the device, in order to achieve double double-backing period as quickly as possible. At the moment of the double-backing period, the first turn is completed, generating high rotation moment [16]. At this stage, the thrower seeks to achieve the best anatomical-biomechanical parameters for the most efficient and favourable entry into the rotation through synchronous myometrial-plyometric muscle contractions across muscle kinetic chains. So, the hammer in the second turn must enter at higher speed than it was the entry into the first. The same principle is used to enter and exit the next three turns. This theory was confirmed in our study for both sub-samples, where from starting speed of about 17m/s, the ejection velocity increased by 11m/s successively, from turn to turn, with maximum speed in the fourth turn at the ejection stage (Table 1 Figure 1-3), which is consistent with research [11]. For instance, according to Y. Sedikh, the speed of rotation is gradually increasing through the turns, so that at the moment of ejection this speed would be record even today (30.7m/s).

The timing of the top throwers' rotation depends on the duration of the number of turns and the speed increment, ranging from 1.64sec. (with 3 turns) up to 2.16 sec. (with 4 turns). Murofushi performed 4 turns in 1.96 sec, Tikhon in 2.04 sec, when reaching a result over 80m, etc. The speed of ejection, if given the hammer at the right angle, is almost always a crucial factor of the end result [1, 6]. When throwing hammers, the action on the long road is not a guarantee of good results, but it is necessary to communicate the maximum force in the shortest time interval [24]. The movement of the hammer is performed with two to three swings, which are then followed by three or four turns in which the thrower rotates in synchronization, the speed of the hammer being steadily increased until the moment of ejection [26]. In the technical embodiment, the circular motion of the hammer around the thrower, the gradual change in the inclination of the plane of movement of the hammer and the horizontal trajectory of the thrower-hammer system within the circle are observed. In the initial part of the throw, the hammer is in the horizontal question, at 37° [8], but becomes steeper as speed increases and reaches incline of about 40° during the last turn. The thrower keeps the hammer in its circular path and the centrifugal force, during the last turn, is transmitted through the wire

to the centre of the ball. In twist, the wire acts equally and opposite to the force of the thrower's hand, which tends to pull it forward [1, 7, 16, 19].

Each gender has characteristics that contribute to success, as different anthropometric differences occur between the genders that cast the hammer and are likely to influence the optimal technique [23]. The most visually noticeable differences are in height and body mass, where male hammer throwers are typically taller and have more mass than their counterparts [4, 5]. The male hammer is proportionally more massive than the female hammer and relative to the body mass, which results in different mastering of the inertia force and the centrifugal force. Therefore, female throwers have higher starting speed due to less body mass, shorter torso and less ball weight, as well as the centre of mass of rotation due to the difference in weight and mass distribution during turns and throws [10, 19, 33]. Women are more upright during throwing because of their lower body mass and lighter weight, so they require less effort than men when confronting inertia forces and centrifugal force [34-37].

Generally speaking, the results obtained in this study for the female sample are partly consistent with previous

research regarding the ejection rate, starting speed, and turning speed of female throwers, especially the first and second turns.

Conclusion

The study was conducted on a sample of 16 finalists at the 2011 Daegu World Athletics Championships to determine differences in kinematic parameters between male and female hammer throwers. The results of the study confirmed differences in all defined parameters, but statistically significant differences of finalists were recorded only in the rate of ejection ($T=3.684$; $p<0.004$) and the speed of the fourth turn ($T=4.396$; $p<0.002$) in favour of men. Consequences of differences can be found in length of training, different training process, competitor experience, morphological profile, motor and anatomical structures, movement technique, biomechanical parameters not taken into the research. Future research could consider a larger number of kinematic parameters and larger number of subjects.

Conflict of interests

The author states that there is no conflict of interests.

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Bilateral asymmetry of pedaling force at different levels of exercise intensity in cycle ergometer

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

Abstract

Purpose: To investigate how bilateral pedaling asymmetries change at exercises with different levels of intensity.

Material: Eight students of cycling, average age 25.4 years, were investigated. In the experiment, we recorded the pedal force of the right and left legs during three consecutive exercises of different intensity 35%, 55% and 85% respectively. To quantify the difference in physical parameters of pedaling between the left and right legs, we used two approaches that complement each other in the analysis of bilateral asymmetry. One approach involved determining an asymmetry index, and other was statistical analysis.

Results: The Student's t-test indicated that the difference between the power samples for the left and right pedals decreased at 85% exercise intensity vs. 55% with a statistical significance of $\alpha = 0.05$. The bilateral asymmetry in most cases decreased or in two cases remained unchanged. The cases where there was no statistically significant difference between the power samples for both legs at 85% and 55% intensity levels had the lowest asymmetry index.

Conclusions: The bilateral pedaling asymmetry is reduced at 85% exercise intensity compared to the 55% one. The reduction in asymmetry index ranges from 1% to 14.1%. Combining the asymmetry index and the Student's t-test can increase the informativeness of pedaling power data when analyzing bilateral asymmetry.

Keywords: cycling, pedal force, bilateral asymmetry, asymmetry index, intensity.

Introduction

Asymmetry in morphology and function between the both sides of the body has long been known. It is also observed in everyday human activities. It is interesting to know how this asymmetry in cycling changes and the factors influence it.

It is well known that higher cycling power is closely linked to the ability to apply effective pedal force. There are several areas in which research could contribute to improving the understanding of the relationship between optimal force effectiveness and performance. Establishing a "natural" range of symmetry of pedal forces should be the goal of future research and may explain the influence of symmetry in cycling performance and injury prevention [1].

Focusing on a segment of the pedalling cycle may well offer improvement in performance [2, 3].

There are many studies on bilateral pedal differences that show some degree of asymmetry in force, torque, performance, and power between the two legs [4]. During cycling, bilateral differences are frequently found and vary with the competitive situation, pedaling cadence, exercise intensity and exercise duration [5]. It was concluded that pedaling asymmetry changes systematically with crank torque output and exercise intensity [6]. The results demonstrate that pedaling asymmetry in trained road cyclists can be consistent across different saddle heights and even at different cycling intensities [7]. Smak et al. conclude that pedaling asymmetry is highly variable

among subjects and that individual subjects may exhibit different systematic changes in asymmetry with pedaling rate depending on the quantity of interest [8].

There are several types of forces acting on a cycle's crank. The *total force* applied perpendicularly to the crank of the pedal in the sagittal plane (the one in which the bicycle moves) consists of two components: *normal force* (direction and perpendicular to the surface of the pedal) and *anterior-posterior force* (it is perpendicular to the normal force). *Effective force* is a percentage of the total force and causes propulsion or stopping of the pedal movement [1].

There is a lot of investigation on the factors that influence the force applied to the pedals. The human ability to develop highest power values in a short time plays an important role in many sport disciplines and every day activity. Power depends on force and velocity [9]. The force-velocity and power-velocity characteristics in cycling typify the function of muscles responsible for pushing on the pedal, especially the hip and the knee extensors [10]. A procedure for decomposing pedal forces into muscular and nonmuscular components was proposed by Kautz S. and Hut M. to provide a theoretical basis for understanding or evaluating pedal forces [11]. Pedal force effectiveness is defined as the ratio between the effective force and the total force applied to the pedal [1].

The relationship between asymmetry and performance is greater for the effective pedaling power and less for total power and the performance index. Substantial asymmetry was found for effective force (36-54%), resultant force

(11-21%), and the Index of effectiveness (21-32%) [12].

Asymmetry in pedaling was found to be highly variable between subjects. They show different systematic changes depending on the speed of pedaling [8]. On the other hand, the increase in torque applied to the crank and the increase in the exercise intensity cause a decrease in the asymmetry of pedaling [6, 13]. Another study shows that asymmetry in peak torque increases at higher load power and this is due to the dominant leg [14].

The quantitative assessment of asymmetry usually involves measuring the asymmetry index left-to-right or statistical procedures [4, 12]. The index of bilateral asymmetry in pedaling varies widely, and the effect of cadence on it is not fully understood. There is agreement in the literature that bilateral differences in cycling power and performance can vary between 5% and 20% [5].

Of great importance for the asymmetry obtained in the various studies is the apparatus used. This is evidenced by the increase in torque differences for the dominant and non-dominant legs when increasing the applied power when different measurement systems are used. The crank-mounted pressure-sensing system showed an asymmetry index of 7% to 33%, and for the strain gauge system using tensometric pedals the index ranged from 9% to 66% [14].

The dominant leg is always responsible for the greater torque of the crank. As the torque increases and the exercise intensity increases, the asymmetry of pedaling decreases [6].

Therefore, we hypothesized how the magnitude of exercise intensity would affect asymmetry in pedaling.

The purpose of the study is to monitor how pedaling asymmetries change at exercises with three different levels of intensity, the latter of which should cause fatigue in participants. We chose a laboratory test because of the greater control over the experiment. In addition, laboratory maximum test data offer a precise way of modeling cycling performance [15].

Material and methods

Participants. Eight students, men, cyclists, average age 25.4 years, was investigated. All were assigned to the same experimental task. In this experiment, informed consent was obtained from all participants.

Procedure.

The investigation was accomplished in one session for each participant. The preferred leg was pre-determined by a "kick to the target" test [16, 17]. The subjects were instructed to measure their resting heart rate after awakening from sleep (HR_{rest}) and to report it to the researchers. This was necessary to determine the exercise intensity. The hardware complex we used in this study consisted of a Monark 618-E bicycle ergometer, a Sigma - Sport heart rate monitor, a laptop, Wi-Fi instrumented pedals, fixed to the bicycle ergometer. The system also includes an interface, created and described by Stefanov [18]. The system measures the normal force. Every one of the students monitored used their own cycling shoes SPD-SL pedal system designed by Shimano. Prior to the test, the maximum heart rate (HR_{max}) of each participant was

theoretically determined according to the Tanaka formula [19].

$$HR_{max} = 208 - 0.7 \times \text{age}$$

The target heart rate (THR), which should be reached and maintained during the three intensity levels, was calculated as 35%, 55% and 85% of the reserve heart rate (HRR), respectively. We used the Karvonen formula to determine the target heart rate:

$$THR = (HRR \times (\% \text{ of intensity})) + HR_{rest},$$

where $HRR = HR_{max} - HR_{rest}$.

After this preparation three consecutive exercise intensity are set without any rest between them with the following levels of intensity and duration:

- *Level I - 35% of HRR*, which is 5% lower than the upper boundary of the area designated as light intensity by [20]. After reaching the THR, the investigated person worked for 4 minutes at such intensity as to keep the heart rate constant. This level plays the role of warm-up.
- *Level II - 55% of HRR*, which is 5% lower than the upper boundary of the area defined as moderate intensity by [20]. After reaching the THR, the investigated worked for 10 minutes with such intensity, that they kept the heart rate constant.
- *Level III - 85% of HRR*, which is defined as a very high intensity area according to [20]. After reaching the THR, the tester works until he can maintain a constant heart rate and pedal cadence or until a subjective feeling of fatigue occurs.

The measurements of the instrumented pedals were monitored by the researcher team throughout the experiment, but recorded in the last 30 seconds on the first two levels of the test to ensure that a steady-state was reached. On the last level longer periods of time were recorded in order to reach the moment of fatigue. The cool-down was then performed at an intensity of about 30% of HRR for 4 min, which ended the experiment.

Throughout the experiment, the subject had to maintain a pedaling cadence of 60 revolutions per minute. At this frequency, we expect a lower error in the reported power [21]. In addition, as pedaling speed increases, asymmetry decreases [8], and we were interested in its manifestation.

During the experiment, we recorded the pedal force of the legs on the left and right pedals every 100 ms of the pedal trajectory. At a cadence of 60 rpm we received 5 measurements for each left and right leg respectively, for each revolution of the pedal. In fact, with this cadence, we get 150 measurements for the left and right pedals in 30 seconds. These measurements were transmitted wirelessly to the laptop. An EXCEL application inserts data directly into the spreadsheet. After the experiment, the inserted data were processed with macros created for the purposes of the study. The instrumented pedal system wirelessly registered and transmitted the force applied on them.

The work done for angular movement (movement angle) can be expressed by the formula:

$$W = F \theta r$$

where: W = work (in J); F = force (in N); θ = angle (in rad); r = radius (m)

At 60 rpm, $\theta = 0.628$, r = radius (m) the length of the crank is 0.165 m

The power (P) with which each leg rotates the pedal for these 100 ms (Δt) is:

$$P = W/\Delta t$$

Statistical analysis.

In the statistical analysis we used the EXCEL program of Microsoft Office Professional Plus 2010, and the statistical program is XLSTAT 2015.

After checking the shape of distribution of the samples by the Shapiro-Wilk normality test. This statistical method stated:

- The null hypothesis H_0 : The variable from which the sample was extracted follows a Normal distribution; and the alternative hypothesis H_a : The variable from which the sample was extracted does not follow a Normal distribution.
- As the computed p -value is greater than the significance level $\alpha=0.05$, one cannot reject the null hypothesis H_0 .

The results of the normality test are presented in Table 1. Represents the p -values from Shapiro-Wilk normality test for the peak power outputs for the left and right legs at an intensity of 35% ((Ll/P) and (Rl/P)), 55% ((Lm/P) and (Rm/P)), and 85% ((Lh/P) and (Rh/P)) of HRR. We found that in most of samples the distribution is normal or close to normal, but in tree samples is not normal. Therefore, we chose nonparametric methods for further statistical processing.

We also use Kruskal-Wallis test (comparison of k samples).

Results

After initially transformation of the received variables into work (W) and then into power (P), we transferred only the peak power for each revolution of pedals for the left and right leg into Table 1. Thus the peak power formed statistical samples for the left and right leg at intensities of 35% of HRR, 55% of HRR, and 85% of HRR described in the methodology.

To quantify the difference in physical parameters of pedaling between left and right leg, we used two approaches that complement each other in the analysis of bilateral asymmetry.

One approach involved determining an asymmetry index (AI), that has been described by different authors, with some differences in the equations due to the differences in the experiments in which they used it. We have chosen the equation for AI used by [6] to study bilateral asymmetry in cyclists.

$$AI\% = [(DO - ND)/DO] 100,$$

where: AI% is an asymmetry index; DO is the measurement of the dominant leg; ND is the measurement from the non-dominant leg. Two of the participants showed dominance for the left leg, which we took into account, when using the equation.

The other approach is statistical. We compared the absolute difference between peak power samples for the left and right pedals at 55% HRR and 85% HRR intensity by Kruskal-Wallis test (comparison of k samples). We used a statistical significance $\alpha = 0.05$. If $p < 0.05$ the two samples differed significantly from each other, and therefore the medians derived from them would also differ statistically significantly.

Presented medians (Tabl. 2) are obtained from the samples with peak power during each revolution of pedals for the left or right leg with one of the three exercise intensities. Figure 1. graphically presents the left and right leg power of one of the participants on the level of 85%

Table 1. Shapiro-Wilk normality test p -values for the peak power outputs for the left and right legs.

Participants	(Ll/P)	(Rl/P)	(Lm/P)	(Rm/P)	(Lh/P)	(Rh/P)
VA	0.707897	0.108736	0.893029	0.68002	0.141679	0.347692
DA	0.864262	0.005072	0.598636	0.299225	0.091959	0.066211
SS	0.294762	0.536652	0.396569	0.757072	0.550043	0.084405
DS	0.033551	0.703211	0.963399	0.556498	0.639237	0.616726
SH	0.363315	0.890008	0.778219	0.748239	0.266807	0.661179
MV	0.619129	0.240705	0.148447	0.214255	0.242388	0.728578
SI	0.654552	0.610454	0.47261	0.748396	0.171393	< 0.0001
SR	0.054444	0.485225	0.97837	0.18201	0.356649	0.156173

NOTE: Ll/P - p -values for the peak power output for the left leg at intensities of 35% of HRR; Rl/P - p -values for the peak power output for the right leg at intensities of 35% of HRR; Lm/P - p -values for the peak power output for the left leg at intensities of 55% of HRR; Rm/P - p -values for the peak power output for the right leg at intensities of 55% of HRR; Lh/P - p -values for the peak power output for the left leg at intensities of 85% of HRR; Rh/P - p -values for the peak power output for the right leg at intensities of 85% of HRR.

intensity of HRR recorded every 100 ms. You can also see the peaks for each revolution of the left and right leg pedals. The left and right leg peaks form the samples we compared.

Table 3 shows the average differences between left right legs in peak power at moderate to very high intensity (Lm / Rm_{diff} and Lh / Rh_{diff}), because those at low intensity (Ll_{diff} / Rl_{diff}) show uncharacteristic changes. At moderate intensity, most participants showed a statistically significant average difference between peak power for the left and right legs, indicating the presence of bilateral asymmetry in pedaling. At 85% intensity, (p-value above 0.05) the average difference between the peak power values for the left and right legs is not statistically significant. Therefore, bilateral asymmetry cannot be demonstrated in very high-intensity pedaling.

Based on both approaches, we made an individual analysis for each participant.

VA - The absolute difference between the medians of the peak power samples of the two legs at an intensity of 85% is greater than the one at the intensity of 55%,

but the samples from which these peak capacities come do not differ from each other with sufficient statistical significance. AI in both conditions changed slightly (1% for the right leg and 1.1% for the left leg), as AI for very high intensity was (-1.1%). Therefore, the asymmetry does not change significantly.

SS - The absolute difference at both intensities is similar, but only the difference between the two legs for a 55% intensity is statistically significant, compared to 85%. The AI for the intensity of 85% is less than that for the moderate intensity by 6.6%. Asymmetry therefore decreases.

MV - The absolute difference is increasing, albeit slightly, at an intensity of 85% compared to that of 55%. The statistical significance of the difference between the two peak power samples at both intensities is high. AI though slightly (3%) decreases. Asymmetry therefore decreases.

DS - The absolute difference increases slightly at an intensity of 85% compared to that of 55%. There was a statistically significant difference between the two

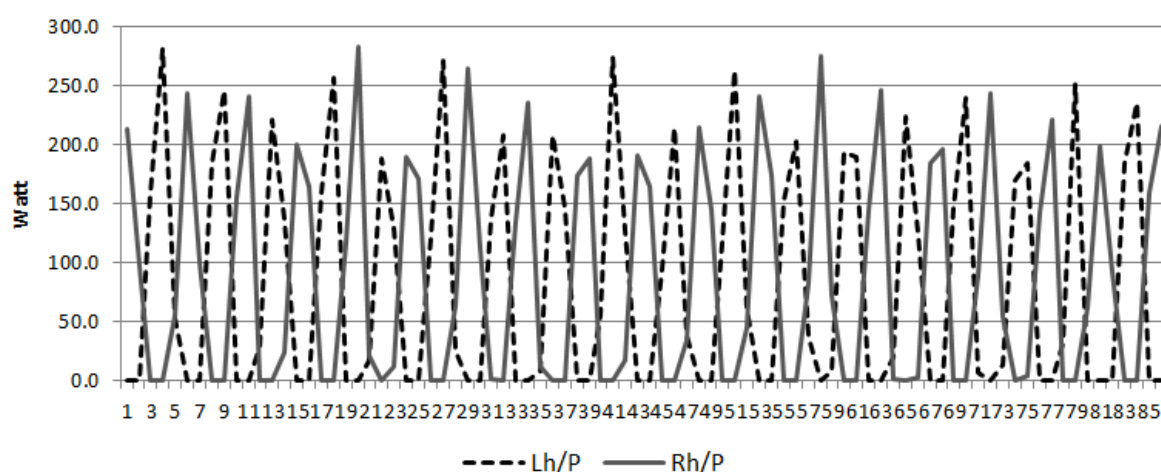


Figure 1. Represents the powers for left Lh / P and right Rh / P leg at an intensity of 85% of HRR. The ordinate shows the power of each measurement and abscissa the number of measurement.

Table 2. Peak power for left and right legs.

Participants	Ll/P (Watt)	Rl/P (Watt)	Lm/P (Watt)	Rm/P (Watt)	Lh/P (Watt)	Rh/P (Watt)
VA	213.8	218.7	235.3	237.7	318.95	315.55
SS	208.7	204.55	158.95	180.75	236.95	253.85
MV	171.4	178.2	223.8	271.9	296.1	346.55
DS	182.85	203.6	230.6	218.1	340.1	332.6
SR	108.9	127.6	144.2	177.9	223.8	235.2
SI	178.1	201	238	263	554.25	604.6
DA	188.9	192.8	262.2	259.9	180.8	175.7
SH	142.85	115.3	151.9	125.45	285	247.8

NOTE: Ll / P - low intensity, left leg peak power; Rl / P - low intensity, right leg peak power; Lm / P - moderate intensity, left leg peak power; Rm / P - moderate intensity, right leg peak power; Lh / P - very high intensity, left leg peak power; Rh / P - very high intensity, right leg peak power.

Table 3. Statistical significance in peak power difference between left and right legs, and AI for moderate and high intensity.

Participants	Lm/Rm _{diff}	Lh/Rh _{diff}	Lm/Rm p - value	Lh/Rh p - value	AI/m%	AI/h%
VA	7.4	31.25	0.74	0.0995	1.0	-1.1
SS	21.5	20.55	<0.0001	0.29	13.4	6.8
MV	40.3	42.8	<0.0001	<0.0001	17.7	14.6
DS	19.2	20.4	0.048	0.31	6.5	1.1
SR	33.1	25.8	<0.0001	0.755	18.9	4.8
SI	30	50.35	0.028	0.083	9.5	8.3
DA	24.3	32.6	0.91	0.69	0.9	2.8
SH	20.75	25.8	0.001	0.000	17.4	13.1

NOTE: Lm / Rm_{diff} - differences in peak power at moderate intensity between left and right legs. Lh / Rh_{diff} - differences in peak power at high intensity between left and right legs. Lm / Rm - statistical significance of the difference between the peak power outputs for left and right leg, at moderate intensity. Lh / Rh - statistical significance of the difference between the peak power outputs for left and right leg, at high intensity. AI / m% - asymmetry index at moderate intensity; AI / h% - asymmetry index at very high intensity.

samples only at moderate intensity, indicating that an 85% intensity difference may be apparent. The very lack of a statistically significant difference between the left and right leg samples at an intensity of 85% indicates little asymmetry. AI decreased by 5.4% at high intensity. Asymmetry therefore decreases.

SR - The absolute difference in high intensity decreases noticeably, but only the difference between the two peak intensity samples at moderate intensity is statistically significant. AI decreased by 14.1%. Asymmetry therefore decreases.

SI - The absolute intensity difference of 85% is greater than that of 55%, but only the one between the two 55% intensity samples is statistically significant. AI declines relatively slightly by 1.2%. Asymmetry therefore decreases slightly.

DA - The absolute difference in high intensity is greater than that of moderate intensity, but the samples from which these differences come do not differ significantly. As AI increases slightly (1.9%), asymmetry cannot be assumed to change.

SH - The absolute differences at both intensities are large, but the difference between them is relatively small. The statistical significance of the difference between the peak power extracts for the left and right legs at both intensities is high. AI decreased by 4.3%. Asymmetry therefore decreases.

If we summarize the analyses for each participant, it can be seen that the bilateral asymmetry in most cases decreases but in two cases remains unchanged. The cases where there is no statistically significant difference between peak power samples for both legs at both intensity levels have the lowest AI.

Discussion

The reduction of bilateral asymmetry with increasing exercise intensity for each of the participants in the experiment was manifested to a different extent. Contingents studied by other authors are similar to the contingent studied by us, with asymmetry reaching 43% [8, 12].

The reduction in AI ranges from 1% to 14.1%, which is similar to the conventional limit from 5% to 20% [5]. These differences in the degree of bilateral asymmetry depend on many factors. One of them is probably the degree of fatigue achieved in each participant. The level of 85% from HRR was intended to cause fatigue, which during the experiment we tried to detect on an external basis, such as inability to maintain pedaling speed, impaired pedaling, heart rate above target, which we defined and the subjective feeling of the participant. From this point of view, the degree of fatigue achieved for each cyclist is different.

Probably important for the degree of bilateral asymmetry is the functional condition of the participant as well as his pedaling technique. According to the preliminary information we received for each of them, those with more experience and higher achievement had lower AI or the difference of AI between the two levels of intensity was smaller.

Reduction of asymmetry of pedaling at high exercise intensity probably depends on the peripheral and central nervous mechanisms. Asymmetry in pedaling seems to be related to the dominance of the legs and is significantly reduced with increasing of exercise intensity. The effect of experience on asymmetry in pedaling is not as clearly defined as it is with asymmetry in running [5]. Future studies on bilateral asymmetry in pedaling should include

larger and more homogeneous contingents from athletes. Standardized exercises similar to those used by us should be applied. We recommend using the complementary approach we use to evaluate bilateral asymmetry.

Conclusions

In conclusion, bilateral pedal asymmetry is reduced at high exercise intensity compared to moderate exercise intensity. Combining the AI and Student's t-test can

increase the informativeness of pedaling power data when analyzing bilateral asymmetry. The lack of statistical significance for the difference between the left and right peak power samples in itself implies also less bilateral asymmetry.

Conflict of interest

The authors declare that there is no conflict of interests.

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Comparison of physical activity and skinfold thickness of students living in rural and city center

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

Abstract

Purpose: In this academic research, it was aimed to compare the physical activity and skinfold thickness of the students living in the city center and rural areas.

Material: 89 students attending the 6th grade level, whose total age is 12 years old, residing in the city center and rural areas of Çanakkale participated in the study. Students were examined with SenseWear armband bmi, total energy consumption, daily step count, met, active energy consumption, physical activity time, reach time and sleep times. Body mass index was determined with Holtain Skinfold Caliper. For the analysis of the dataset, the Independent Sample t test was utilized to examine the difference between the students' physical activity levels and skin fold thickness. Then, the relevance between physical activity level and skinfold thickness was examined for pearson correlation. Significance value $p < .05$ and $p < .01$ were accepted.

Results: In accordance with the data obtained with SenseWear Armband, it has been determined that a statistically substantial amount of difference between BMI total energy consumption und daily step number of students living in rural and city centers is present. According to the results of skin fold thickness measurements made with skinfold calipers, there was a significant difference in triceps, subscapular, abdominal, suprailiac and femur regions ($p < .05$).

Conclusions: As a result of the research, it is concluded that students studying in the city center have less physical activity level than students living in the rural area.

Keywords: adolescent, physical, skinfold thickness. sport, children.

Introduction

The notions of physical activity, exercise and physical fitness are frequently used for each other in an interchangeable manner. Nevertheless, these three terms refer to different definitions. Physical activity is a lifelong lifestyle by adopting an active lifestyle in children and adolescents. School-age children get the chance to do physical activity activities through physical education and sports lessons and extracurricular activities [1]. However, some factors such as the environment in which students live, socio-economic level and education level or parents are tractors that determine the degree of physical activity.

Although physical activity degree is the basic element of health and physical development in childhood, physical activity degrees of children decrease day by day. Children and adolescents are recommended to perform physical activity for minimum 60 minutes per day by Disease Control and Prevention Centers [2]. This perspective is mostly reinforced by cross-sectional studies conducted by US samples [3]. In addition, there are studies stating that the deterioration of physical activity started in both genders during school entry [4, 5]. Teens are subject to critical emergencies and long dated health problems such as obesity, feeble bones and possible heart illness by limited physical activity and surplus of sedentary behavior. Children and adolescents in the obese class are in the imperilment of cardiometabolic disease, metabolic syndrome [6, 7].

Physical activities are classified considering the

intensity of the activity [8]. Different levels or intensity are experienced during physical activity. This intensity depends on the person's exercise experience and fitness level. Metabolic equivalent (MET) is used to express this density. MET value is a standard method that defines the absolute intensity of physical activity. 1 MET equals 1 Kcal cuiorie consumption per kilogram of body weight per hour. It also equates to 3.5 millilitres (ml) of oxygen consumption per kilogram of body weight per minute. Body mass index bioimpedance [9], skinfold caliper [10], dexta, bod pod [11], etc. can be measured with many tools and methods [12, 13].

In addition to the physical activity level, body mass index (BMI) is a method utilized to approximate obesity or critical fat values. In estimating this value, a calculation based on height and body weight is used. This calculation is the dividing the weight in kilograms by the square of the length in meters. BMI, general sedentary people are a useful tool for evaluating individuals. However, caution should be exercised when evaluating athletes with large muscle mass, as this method cannot recognize the difference between lean body mass and fat mass und fat distribution.

Like the physical activity level and BMI, skinfold thickness is also a method used to estimate obesity or critical fat values. It is also a practical method used to evaluate body composition. This method is expressed as the measurement corresponding to the amount of subcutaneous fat and two skin thicknesses. With this method developed based on the principle that half of the body adipose tissue is under the skin, skin fold

measurement is made from various parts of the body and body fatness is estimated by equations.

When the previous academic studies in the literature investigating the levels of physical activity are examined, it is seen that they are examined by considering different variables. Some studies show that physical properties (weak, overweight, etc.) are classified through a standard equation such as BMI. For this reason, in this study designed to understand the differences between physical activity levels of rural and urban centers, a more objective study was designed by taking the skinfold thickness measurements. In this study, it was aimed to compare the physical activity and skinfold thickness of the students living in the urban and rural areas.

Material and Methods

Participants. 89 students from the 6th grade, who are 12 years old, living in the city center and rural areas of Çanakkale participated in the study. While rural students constitute 51.7% (n = 46) of the research, students studying in Çanakkale city center made up 48.3% (n = 43) of the study. While the average height of students living in rural areas is 154.652 ± 6.899 , the average weight is 45.934 ± 10.609 . The average height of students living in the city center was 160.395 ± 7.020 , while the average weight was 53.740 ± 11.740 .

Research Design.

In this study, causal comparison was used as a research design. No intervention was made for either group (12-year primary school students living in rural and city center).

Data Collection Tools

SenseWear Armband: SenseWear Armband is a portable device for measuring energy consumption, daily

step count, rest time and many other parameters such as MET value, taking into account some personal features such as weight, height, age. SenseWear Armband is used by wearing on the triceps muscle of the right arm of the participants. With Sensewear armband, brni, total energy consumption, daily step count, met, active energy consumption, physical activity time, resting time and sleeping time were examined. Holtain Skinfold Caliper: Holtain brand skinfold caliper, which applies 10 gr / sq mm pressure, was used to determine the body fat ratio.

Statistical Analysis

After collecting the research data, it was determined that skewness and kurtosis coefficients were controlled and distributed normally. It was determined that the skewness values of the variables were between -0.62 and -0.89, while the kurtosis values were between -0.29 and 0.81. According to Tabachnick and Fidell [14], the skewness and kurtosis values between + 1.5 and -1.5 are indicators for using parametric tests in data analysis. Due to the normal distribution of data, the Independent Sample t test was applied to examine the difference between the physical activity levels and skinfold thickness of students studying in the city center and students studying in rural [14]. Then, the correlation between physical activity level and skinfold thickness was examined. The significance value was accepted as $p < .05$ and $p < .001$.

Results

According to the results of independent sample t test conducted in accordance with the data obtained with SenseWear Armband, BMI, total energy consumption and the number of daily steps were found to be statistically significant differences. It was found that there was

Table 1. Independent Sample T Test Results of Physical Activity and Skinfold Thickness of Rural and Urban Students

Variables	Region	n	X	Ss	Sd	t	p
BMI	Rural	46	19.11	3.80	87	2.567	.012
	Urban	43	21.13	3.59			
Total Energy Consumption	Rural	46	2199.60	481.37	87	-4.410	.000
	Urban	43	2624.83	423.89			
Daily Step Count	Rural	46	18564.54	4494.62	87	2.807	.006
	Urban	43	16118.53	3649.23			
MET	Rural	46	2.03	.25	87	1.506	.136
	Urban	43	1.95	.22			
Active Energy Consumption	Rural	46	947.89	326.72	87	-1.593	.115
	Urban	43	1064.65	364.68			
Physical Activity Time	Rural	46	261.65	90.43	87	-1.064	.290
	Urban	43	242.27	80.65			
Resting Time	Rural	46	507.71	70.73	87	.371	.711
	Urban	43	502.88	49.43			
Sleep time	Rural	46	391.15	65.64	87	.918	.361
	Urban	43	378.69	62.05			
Triceps	Rural	46	13.48	6.98	87	-5.030	.000
	Urban	43	20.36	5.80			
Subscapular	Rural	46	13.44	6.76	87	-2.488	.015
	Urban	43	16.73	5.60			
Abdominal	Rural	46	15.61	7.97	87	-4.180	.000
	Urban	43	22.06	6.44			
Suprailiac	Rural	46	14.90	8.73	87	-2.619	.010
	Urban	43	19.14	6.23			
Femur	Rural	46	21.52	8.44	87	4.362	.000
	Urban	43	28.33	5.98			

Table 2. Correlation Analysis Results of SenseWear and Skinfold Thickness Measurement Values

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1												
2	.762**	1											
3	-.062	.196	1										
4	-.272**	.022	.669**	1									
5	.382**	.693**	.587**	.602**	1								
6	-.149	.119	.668**	.889**	.678**	1							
7	-.034	-.118	-.060	-.186	-.140	-.099	1						
8	.098	-.137	-.251*	-.273**	-.257*	-.198	.514**	1					
9	.689**	.684**	-.085	-.277**	.283**	-.223*	-.135	-.062	1				
10	.819**	.709**	-.038	-.328**	.285**	-.244*	-.135	.024	.752**	1			
11	.769**	.711**	-.139	-.320**	.269*	-.219*	-.157	-.070	.881**	.839**	1		
12	.832**	.710**	-.014	-.328**	.317**	-.242*	-.169	-.026	.781**	.908**	.906**	1	
13	.750**	.687**	-.136	-.353**	.217*	-.315**	-.041	-.026	.826**	.859**	.874**	.872**	1

NOTE: 1.Bmi, 2.Total Energy Consumption, 3 Daily Step Count, 4. MET, 5. Active Energy Consumption, 6. Physical Activity Time, 7. Resting Time, 8. Sleep Time, 9. Triceps, 10. Subscapular, 11. Abdominal, 12. Suprailiac, 13. Femur.

no statistically difference between active energy consumption, physical activity time, resting time, sleep time. According to the results of measurement of skinfold thickness made with skinfold caliper; triceps, subscapular, abdominal, suprailiac and femur regions were found to be significantly different (Table 1).

After analysing the Table 2, a meaningful positive correlation is found out between BMI and total energy consumption, active energy consumption, triceps, subscapular, abdominal, suprailiac, femur while a negative correlation is found between BMI and MET value. A negative meaningful correlation is discovered between total energy consumption and active energy consumption, triceps, subscapular, abdominal, suprailiac, femur. While a positive meaningful correlation is found out between daily step count and active energy consumption and physical activity time, a negative correlation is found out between daily step count and sleep time. While a positive correlation is determined between MET value and active energy consumption, physical activity time, a negative correlation is determined between MET value and triceps, subscapular, abdominal, suprailiac, femur. A positive correlation is found out between active energy consumption and physical activity time, sleep time, triceps, subscapular, abdominal, suprailiac, femur. A negative correlation is determined between physical activity time and triceps, subscapular, abdominal, suprailiac, femur.

Discussion

In this study which is conducted to estimate similarity or dissimilarity between the physical activity levels of children in rural and urban centers; It was determined that statistically substantial amount of difference between BMI, total energy consumption and daily step count is present.

It was determined that there was no statistical difference between MET, active energy consumption, physical activity time, resting time and sleep time. According to the measurement of skinfold thicknesses made with skinfold caliper, there was a significant difference in triceps, subscapular, abdominal, suprailiac and femur regions (Table 1). a meaningful positive correlation is found out between BMI and total energy consumption, active energy consumption, triceps, subscapular, abdominal, suprailiac, femur while a negative correlation is found between BMI and MET value. A negative meaningful correlation is discovered between total energy consumption and active energy consumption, triceps, subscapular, abdominal, suprailiac, femur. While a positive meaningful correlation is found out between daily step count and active energy consumption and physical activity time, a negative correlation is found out between daily step count and sleep time. While a positive correlation is determined between MET value and active energy consumption, physical activity time, a negative correlation is determined between MET value and triceps, subscapular, abdominal, suprailiac, femur. A positive correlation is found out between active energy consumption and physical activity time, sleep time, triceps, subscapular, abdominal, suprailiac, femur. A negative correlation is determined between physical activity time and triceps, subscapular, abdominal, suprailiac, femur (Table 2).

The level of physical activity has been the subject of discussion by researchers considering different situations in child age groups. Therefore, different research results are included in the literature.

When the physical activity is examined according to the status of being boys and girls in terms of socioeconomic terms.

Drenowatz et al. stated that physical activity of children with low socio-economic level is higher than that of children with high socio-economic level [15]. Matsudo et al. investigated the correlation between overweightness / obesity and socioeconomic level using accelerometer [16]. As a result of the research, they stated that there is no relationship between socio-economic level and overweightness/obesity. O'Donoghue et al. examined physical activity level and socio-economic level according to different age groups. As a result of the research, they did not find any relationship between the physical activity level and socio-economic level in preschool, school-age children and adolescents [17]. In a study conducted in Turkey based on socio-economic levels in children aged 11-13 were examined physical activity levels, it is stated that there is no relationship except for height and coordination value [18].

Parks et al. provided important information to the literature in their study to examine the relationship between various demographic characteristics (environmental, geographical, socio-economic level) and physical activity levels of rural and urban areas [19]. As a result of the study, they stated that individuals with low income level s had lower physical activity levels and physical activity planning status than individuals with high income levels. In addition, it has been determined the physical activity level are important according to income level and rural or city center settlements.

Troiano et al. examined the physical activity level s of children (6-11 years old), adolescents (12-19 years old) and adults (20+ years old) using the accelerometer [20]. According to the results of the research, they found that activity level of men is higher than that of women, and the level of physical activity decreases significantly as people grow older. In addition, 42% or children between the ages of 6 - 11 and 8% of adolescents between the ages or 12 - 19 reached the target of 1hour physical activity. Those who reached the 30-minute physical activity target in adults over 20 were round to be less than 5%. There is a comparable research by Møller et al. [21]. In the research, physical activity levels or Danish children were examined in 1997/1998 and 2003/2004. As a result of the research, no difference was found according to the socioeconomic level when compared with 1997/1998 and 2003/2004.

When the physical activity levels of children are examined according to the rural and urban center;

Joens - Matre et al. compared the physical activity levels of four, five and sixth grade students studying in rural and city center [22]. As a result of the research, it has been determined that the students studying in rural areas have higher physical activity levels compared to their children studying in the small city-town and city center. They stated that this was due to the fact that children had more physical activities in the countryside alter school and in the evening.

Johnson et al. discussed five studies in a systematic meta-analysis they conducted and compared children between the ages or 2- 19, urban and rural [23]. As a result of the study, it was concluded that the obesity levels of

children from rural areas are higher than the that of the children from urban in other studies, except one study.

Liu et al. compared physical activity, physical fitness and overweight in children aged 2-11 years, according to rural and urban life situations [24]. As a result of the research, they found that rural children consume 90 kcal more food than the children living in the urban center, they consume 2-3 cups of milk recommended per day, and they participate more in the exercise. However, according to the comparison made using height weight data, rural children were more susceptible to overweight / obesity than the urban children. We think that this situation, which does not coincide with the results of our research, is due to the fact that a judgment is made by considering only the height and weight data without calculating the fat or lean body weight.

McMurray et at. studied children studying in rural and urban areas in terms of socio-economic, gender and race, in terms of risk of cardiovascular disease, physical activity and obesity [25]. In this study, it was concluded that there was no difference in the total cholesterol, blood pressure, smoking und physical activity levels of the children studying in rural and urban centers. In addition, body mass index and skinfold thickness und obesity were round to be higher in rural areas. This situation, which does not coincide with the results of our research, can be advocated with the idea that urban living conditions in 1999 were not affected by urbanization and technological developments (areas for transportation, use of elevators, physical activity).

Levels or physical activity and physical fitness of Colombian children and adolescents are investigated by Prieto-Benavides et al. with objective measurements [26]. In a study with 149 children and adolescents (9-17.9 years), physical activity by making use of an accelerometer. Physical fitness was measured by weight, height, waist circumference, hip, waist measurement and skinfold thickness mom subscapular / triceps region. In conclusion, high physical activity level and skinfold thickness were found to be inversely related in boys and girls.

Armstrong et al. examined the variables of age, gender, body mass und obesity, and physical activity levels of children aged 11 -13 [27]. Consequently, it has been determined that the children with 139 middle 159 high activity classes decrease their physical activity levels as the age progresses, and body mass and obesity are not a significant variable separating both groups. Moore et al. designed a different study [28]. Physical activity levels of adolescents living in urban and rural areas and the reasons that impede or facilitate the activity are investigated in this study. As a result of the research, it was stated that young people living in both rural and urban areas do not meet the recommended physical activity levels. In addition, it has been stated that tractors such as distance, cost, crime, and television make it difficult for young people, and facilitates such as facility facilities, social environment-peer and family role models facilitate physical activity.

Collins et id. contrasted the activity levels of rural

adolescents with slums close to the city center, in a study in Staffordshire, England [29]. In the study, where measurements were taken with the help of GPS, it was found that adolescents living in slums participated in more physical activities than rural adolescents. When this situation is evaluated together with other researches, it has revealed a new dimension in determining the variables. It is understood that those living in the city center and those living in the slums in the city can reveal different parameters.

Plotnikof et al. examined the physical activity levels of 20606 people living in Canada in terms of age, gender and rural-urban [30]. As a consequence of the research, dissimilarities between physical activity levels in rural and urban areas were determined. According to the age groups, physical activity levels vary.

In another study conducted in Canada, Loucaides et al. investigated the physical activity levels of urban and rural students [31]. In the study conducted with 1398 students living in urban areas and 1290 students from rural areas, no difference was found in terms of physical condition, self-efficacy and recreation activities in both settlements. However, it has been determined that female students are less active than male student.

In a research done in Taiwan, Sheu-jen et al. compared the physical activity levels of school-age children as urban and rural areas [32]. In the study, in which 523 elementary school students participated, there was no difference in terms of walkability in urban and rural areas. In terms of accessibility, children living in urban areas are more active physically. Children are determined to be more active in terms of physical activity after school, on weekends and holiday.

In a study based on a different variable apart from all these variables, seasonal conditions were prioritized

while examining activity levels. Constantinou et al. measured the activity levels of children living in the Greek Cypriots using pedometer and found significant differences between rural children and urban children [33]. As a result of this study, where measurements were carried out in two different seasons: summer and winter, it was observed that children living in the countryside showed higher activity levels compared to children living in the countryside, while children from the city reached higher activity levels than children living in the countryside. This has been interpreted by the researchers that rural children live in the summer because of their lives, because they live closer to home in winter. Again, it was commented that children in the city move less in the summer and that in winter they have the chance to do more activities in closed and safe environments.

Conclusion

As a result of the research, it is concluded that students studying in the city center have less physical activity level than students living in the rural area. Another conclusion is that the low level of physical activity of students living in the city center also negatively affects their physical fitness levels. In this context, it may be recommended to inform students and parents about activities to increase the physical activity level of students living in the city center. Students can be enabled to participate in extra-curricular sports activities.

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Conflict of interest

The authors declare that there is no conflict of interests.

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