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Original Article

Sex-mediated differences and correlations between the anthropometric characteristics and motor abilities of university students

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Abstract
The aim of this study was to evaluate sex-mediated differences, and the correlations, between anthropometric characteristics and motor abilities of university students performing various motor tests. The study was conducted between 2000-2018 on 4956 first-year full-time female students and 4551 male students (20.0±1.0 years total for both sexes). The participants' body mass and height were measured, and their BMI was calculated. Motor abilities were evaluated in 13 motor skill tests. The recorded values of body mass, height and BMI were significantly higher in men than in women (percentage values: 22.8%, 8.9% and 6.8%; Sexual dimorphism indicator (SD): 1.96, 2.56 and 0.53). The greatest differences in the values of the SD indicator were observed in the 12-minute rowing ergometer test: (37.6%, SD - 3.53), medicine ball backward and forward throws (37.77 and 37.48%, SD – 2.28 and 2.27), and standing long jump (23.98 %, SD - 2.51). In both sexes, BMI was significantly ($p<0.001$) negatively correlated with all motor tests, excluding medicine ball throws (positive correlation, $p<0.001$) and 1-minute Burpee test (not significant in women). The correlations between body height and motor tests differed between sexes. Male students were characterized by significantly higher levels of anthropometric characteristics and motor abilities, whereas females performed better in flexibility tests. The advantage of men over women was highest in endurance and strength abilities, and lowest in speed/agility abilities. Body mass was significantly negatively correlated with all motor tests, excluding medicine ball backward and forward throws (positive correlations and no correlation in one case). Significant positive correlations were noted between motor tests evaluating the same motor abilities.
Keywords: university students, anthropometric traits, motor abilities, motor tests, sex differences

Introduction

In humans, sex-mediated differences in anthropometric characteristics and motor abilitiesare apparent in all stages of life. These differences should be explored to provide valuable information in many practical settings, particularly in physical education and youth sports.Motor fitness may be consideredas a measure of an individual's adaptation to the biological, geographic and socioeconomic environment, which is why the correlations between motor abilities and other factors should be investigated. It appears that sex differences in motor abilities are explained by the interactionsbetween environmental and biological factors(Kolokoltsev,Iermakov, &Jagiello, 2018;KubaisyMohamad, Ismail, & Abdullah, 2015;Malina&Bouchard, 1991;Raudsepp&Pääsuke, 1995). The heritability of athletic status is estimated at 66% (De Moor et al., 2007),and aquantitative trait locus (QTLs)that differs by more than two standard deviations can exert a significant influence on the components of athletic performance, which suggests that genetic markers could be associated with human somatotypes (Szalata, Słomski, Balko, & Balko, 2019) and motor performance. Single nucleotide polymorphisms (SNPs) maypartly explain individual differences in response to exercise and training (Gronek et al., 2018), whilst some SNPs are associated with selected motor abilities (Karpowicz,Krych, Karpowicz, &Gronek, 2018).

Previous studies have established that body composition affects various measures of motor fitness and motor performance (Malina, 1975).Therefore, humans with different somatotypes demonstrate unique performance capacities during exercise and physical training (BolonchukSiders, Lykken, &Lukaski, 2000).In general, differences in motor performance are explained by biological variables (age, height, weight, body fat) in only 30%, on average. These findingssuggest that other factors contribute tomotor performance in prepubertal

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children (Hasley,East, & Stillwell,1982). The level of motorabilities curvesfor most motor performance tasks are relatively similar. In preschool and elementary school students, minorsex differences in motor performance were reported in favor of boys(Halverson,Roberton, &Langerdorfer, 1985; Podstawski&Borysławski, 2012;Raudsepp&Pääsuke, 1995). Sex differences become more apparent during puberty, throughout adolescence and inearly adulthood (Branta,Haubenstricker, &Seefeldt, 1984; DeOreo& Keogh, 1980; Espenschade& Eckert, 1980).Developmental aspects and sex differences in fundamental movement patterns are usually examined based onthe movement kinematics of preschoolers to middle school students (Fortney, 1983; Halverson et al., 1985; Kubaisy et al., 2015; Milne,Seefeldt, &Reuchlein, 1976; Nelson,Thomas, Nelson, & Abraham, 1991; Roberton,Halverson, &Landergorfer, & Williams, 1979; Thomas & French, 1985). Most of the relevant research was carried out between the 1970s and the 1980s; although the correlations between anthropometriccharacteristics and motor abilities have beenstudied more extensively in recent decades (Benefice,Fouere, & Malina, 1999; Milanese, Bortolami, Bertucco, Verlato, &Zancanaro, 2010; Podstawski&Borysławski, 2012).

The above also applies to young adults and adults, but research conducted as early as in the 1930s focused mostly on athletes (Cozens, 1930; Cureton, 1941; Siders, Lukaski, &Bolonchuk, 1993; Sills, 1950; Sills &Michen, 1957; Tanner, 1964; Tanner,Israelson, & Whitehouse, 1960).

Anthropological studies of Olympic athletes consistently show that individuals competing in the same athletic event have similar somatotypes, regardless of their geographical, cultural, or economic backgrounds, whereas athletes participating in different athletic activities have diverse somatotypes(Bolonchuket al., 2000; Carter, 1970; De GarayLevine, & Carter, 1974).

Research into the influence of high workloads on the female body has revealed that female athletes still fall 10% short of male results on average (Jaskólski&Jaskólska, 2006).Many physiological parameters are significantly correlated with body mass and height (Kozina et al., 2016;Kozina et al., 2017).On average, adult women are 7-8% shorter (8-12 cm) and 25-30% lighter (12-18 kg) than men from the corresponding age group (Jaskólska&Jaskólski, 2006). However, men and women differ most significantly in strength abilities (Linde et al., 1997). Lower limb and upper limb strength are 25-30% and 40-60% lower in women than in men, respectively. Theseabsolute differences decrease when strength is expressed relatively in terms of kilograms of body mass (5-15%), and they are even smaller when strengthis determined in terms of kilograms of fat-free mass (Jaskólska&Jaskólski, 2006).

In maximal incremental exercises, the cardiovascular response is equivalentinwomen and men, but the attained maximal valuestend to differ between the sexes. In absolute terms (liters per minute), VO_{2max} is generally 40-60% higher in males than in females (Astrand, 1953;Sparling, 1980). However, when VO_{2max} is expressed in relative terms (milliliters per kilogram per minute), the differences between the sexes decrease to 20-30%. These variations are further decreased to 0-15% when VO_{2max} is determined in relation to fat-free mass (milliliters per kilogram of fat-free mass per minute) (Sparling, 1980).Tests where VO_{2max} is expressed relative to fat-free mass provide valuable information about the influence of adiposity and fat-free mass on VO_{2max}. However, this is not a pragmatic approach to the expression of VO_{2max} because,practically, oxygen is never consumed in relation to fat-free mass alone, and fat-free mass cannot be disregarded during exercise.

Males have greater oxygen-carrying capacity than females because they have approximately 6% more red blood cells and 10-15% more hemoglobin than females (Astrand& Rodahl, 1986),whilst maximal cardiac output is generally 30% higher in men than in women (Wells & Plowman, 1983). Maximal stroke volume is also higher for men, but the increase in stroke volume during maximal exercise relies on the same mechanisms in both sexes (Sullivan,Cobb, & Higginbotham, 1991),and differences are not observed in maximal stroke volume, which is expressed relative to body mass; whilst maximal HR remains indistinguishable betweensexes.

Females exhibit lower levels of physical exercise performance than males, which can also be attributed to the fact thatsexaffectsmotivation for performing regular exercise. According to the United StatesDepartment of Health and Human Services (2008), the variations in exercise performance are related to personal, social, economic, and environmental factors indifferent age groups.Indeed, Irwin (2004)observedsex differences in physical exercise performance, where females were less active than males. It seems that sexis responsible for differences inmotivationfor performing regular physical exercise. Men possessgreater muscle mass and strength than women, but an analysis of the correlations between sex differences and age produced conflicting results (Lindle et al., 1997). In fact, some scholars have suggested that sex differences in certain physical abilities are greater than subgroup differences relating to any other human ability or characteristic (Ployhart,Schneider, & Schmitt, 2006).These differences were not limited to motor performance tests, and similar variations were noted in the corresponding motor performance criteria (Gebhardt & Baker, 2010; Sackett & Wilk, 1994).

The ideal body composition and somatotype for participating in competitive sports differ across disciplines, but these relationships are less pronounced in sedentary individuals. University students are a social group with one of the lowest reported levels of physical activity (American College Health Association-National College Health Assesment [ACHA-NCHA], 2006; Bray & Born, 2004; Grubbs & Carter, 1995; Pribis,Burtnack, McKenzie, & Thayer, 2010).

The vast majority of motor development studies have reported sex differences in anthropometric characteristicsand motor performance variables. The reporting of significant correlations between anthropometric characteristics and motor abilities is growing in the scientific literature, which can also be attributed to the growing number of overweight youths (Hales,Carroll, Fryar, & Ogden 2017), including university students (Mikolajczyk et al., 2010; Peltzer et al., 2014).There is no scientific evidence to explainsex differences in specific motor abilities; where studies examiningsex differences and age have produced conflicting results, and performed on relatively small samples,in limited age ranges (Lindle et al., 1997). These correlations should be examined further in larger samples of young men and women. Thus, the aims of this study were to examine sex-mediated differences in anthropometric characteristicsand motor performance,and to investigate therelationshipbetween anthropometric traits and motor abilities in university students.

Materials and methods

Participants

The present study involved 4956 first-year full-time female studentsand 4551 male students, who were randomly selected from groups of students attending obligatory physical education (PE) classes at the University of Warmia and Mazury (UWM) in Olsztyn, Poland, between2000-2018. The research was conducted every two years, in the summer semester, at the end of April and at the beginning of May.Students were selected randomly on a voluntary basis, and those who wished to participate signed an informed consent form. If the chosen student did not wish to participate in the study, another potential candidate was randomly drawn. Only those students who were absent, for whatever reason, on the day the tests and measurements were performed, were excluded from the study. The participants were selected from among volunteers who did not take any medication or nutritional supplements, were in good health, and had no history of blood diseases or diseases affecting biochemical and biomechanical factors.

Ethical statement

The research was carried out upon the prior consent of the Ethical Committee of the UWM in Olsztyn. The study involved male and female student volunteers who signed a written statement of informed consent.

Instruments and procedures

Body mass (to the nearest 0.1 kg) and body height (to the nearest 0.1 mm) were measured using a calibrated medical scale with a stadiometer (WB-150 ZPU Tryb Wag, Poland), and the results were used to calculate the participants'BMI. Student volunteers participated in thirteen motor ability testswhich assessed their**speed/agility abilities:**4×10 m shuttle run [s], 8s skipping with hand clapping (SHC) test [number of claps], zig-zag run [s], **flexibility abilities:**standing forward bend [cm], barbell overhead trunk rotation [cm], **strength abilities**: standing long jump [cm], sit-ups in 30s [number of sit-ups], medicine ball (4 kg) forward throw [cm], medicine ball (4kg) backward throw [cm], flexed arm hang on bar [s], **strengthendurance:**1-minute and 3-minute Burpee tests (1-MBT, 3-MBT) [number of cycles], and **endurance abilities:** 12-minute Cooper test on a rowing ergometer [m] (Podstawski et al., 2017). In each group, motor ability tests were conducted in the same order, beginning from speed, agility, flexibility and strength tests, and ending in endurance and strength tests. The instructions for each test were given during the PE class, and students were allowed sufficient time to practice. The participants performed an active warm upfor 10 minutes before each test (Frandkin,Zazryn, &Smoliga, 2010).

Statistical analysis

The results of every trial were averaged, and standard deviation was computed using descriptive statistics. Maximum and minimum values were determined to classify the participants into the applicable ranges for every test. The strength and nature of the correlations between anthropometric characteristics and motor abilities were determined in Pearson's linear correlation analysis. The significance of differences between the mean values of anthropometric parameters and motor abilitieswas investigated with the use of Student's t-test. Sex differences in anthropometric characteristics and motor performance were examined by calculating the sexual dimorphism (SD) indicator based on the formula proposed by Szopa (Jaworski, 2005):

$$SD = \frac{2(x_m - x_f)}{S_m + S_f}$$

where:

x_m– arithmetic mean of male students in a given age group, -
x_f–arithmetic mean of female students in a given age group, -
S_m–standard deviation of male students in a given age group, -
S_f–standard deviation of female students in a given age group. -

Results

The tested anthropometric and motor parameters could be directly compared between the sexes due to considerable similarities in the age of the evaluated female (20.0±1.09) and male students (20.0±1.04) (Table 1).

Table 1. Statistical analysis of anthropometric parameters and motor abilities in women and men

Parameter	Women *N*=3955	Men *N*=2691	SD indicator	Difference (%)	Differences in Student's t- test
	***M* ±*SD* (*min÷max*)**	***M* ±*SD* (*min÷max*)**			
Age	20.0±1.09(19÷25)	20.0±1.04 (19÷25)	0.0039	0.02	0.15
Body mass	59.1±7.79 (40.0÷101.3)	76.6±9.94 (55.2÷120.6)	1.9687	22.80	**80.05**
Height	165.06±6.47 (139.8÷195.0)	181.12±6.08 (160.2÷202.225)	2.5600	8.87	**101.81**
BMI	21.76±3.16 (15.02÷38.22)	23.34±2.79 (16.22÷36.33)	0.5306	6.76	**20.95**
Standing long jump [cm]	161.37±19.21 (95.00÷220.00)	210.77±21.26 (139.20÷278.50)	2.5150	23.98	**98.51**
8-s SHC [number of claps]	22.6±3.2 (13÷37)	24.9±3.83 (7÷37)	0.6586	10.29	**25.84**
4×10 m shuttle run [s]	12.67±1.11 (10.03÷27.00)	10.72±1.53 (9.15÷19.27)	-1.4772	-18.16	**60.19**
Zig-zag run [s]	29.59±2.49 (21.61÷38.62)	24.82±2.81 (18.70÷30.98)	-1.7982	-19.21	**61.09**
Downward bend from standing position [cm]	8.0±6.3 (-20÷32)	7.1±6.6 (-22÷24)	-0.1379	-12.48	**5.54**
Barbell overhead trunk rotation [cm]	68.7±5.82 (53÷87)	83.3±13.2 (52÷138)	1.5376	17.53	**52.10**
Burpee Test - 1 min [number of cycles]	21.15±5.09 (2÷32)	23.84±2.34 (4÷32)	0.7226	11.27	**25.59**
Burpee test - 3 min [number of cycles]	47.9±11.17 (4÷72)	57.8±9.5 (22÷82)	0.9652	17.23	**31.76**
Rowing ergometer - 12 minutes [m]	1581.0±230.03 (489÷2166)	2535.0±309.8 (1447÷2998)	3.5346	37.64	**121.30**
Sit-ups - 20 s (core strength)	19.3±4.47 (3÷35)	27.3±4.8 (2÷36)	1.7251	29.45	**69.50**
Medicine ball backward throw [cm]	644.8±153.45 (90÷1250)	1036.3±189.5 (485÷1745)	2.2825	37.77	**91.09**
Medicine ball forward throw [cm]	546.3±119.14 (232÷1075)	873.9±169.3 (192÷1283)	2.2714	37.48	**78.07**
Flexed arm hang on bar [s]/Chest-to-bar pull-ups [number of pull-ups]	9.6±13.19 (0÷129)	4.7±3.1 (0÷23)	**	**	**

Note: Values in bold are significant at $p \leq 0.01$,**- motor tests measuring different motor abilities.

In an evaluation of anthropometric traits, the recorded values of body mass,heightandBMI were significantly higher in men than in women (percentage differences: 22.8%, 8.9%, and 6.8%; SD: 2.0, 2.6, 0.5). The average BMI values were within normal ranges in both sexes (21.8±3.2 and 23.3±2.8 kg/m^2). In motor tests that required strength, speed and endurance, men obtained significantly better results, whereas women performed significantly better in flexibility tests.The highest values of the SD indicator and the greatest percentage differences in SD values were noted in the endurance trial: 12-minute rowing ergometer trial (3.5), explosive strength trial: standing long jump (2.5), and strength trials: - medicine ball backward and forward throws (2.0 for both trials). The smallest differences between the sexes were observed in speed/agility trials: 8-s skipping with hand clapping trial (-0.7), zig-zag run (-1.8), and 4×10m shuttle run (-1.5).

Correlation coefficients were calculated to assess the strength and direction of the relationships between anthropometric parameters and motor abilities (Tables 2 and 3).

Table 2. Correlations between anthropometric parameters and motor abilities in women (N=3955).

No	Motor test	Body mass	Body height	BMI
1	**Standing long jump [cm]**	**-0.0429**	**0.3077**	**-0.2204**
2	**8-s SHC [number of claps]**	**-0.2104**	**0.2682**	**-0.3496**
3	**4×10 m shuttle run [s]**	**-0.1098**	**-0.1340**	**-0.1801**
4	**Zig-zag run [s]**	**-0.0813**	**-0.0915**	**-0.1328**
5	**Downward bend from standing position [cm]**	**-0.0514**	**0.1638**	**-0.144**
6	**Barbell overhead trunk rotation [cm]**	**-0.0798**	**-0.0618**	**-0.1084**

7	1-min Burpee Test [number of cycles]	**-0.2151**	**-0.3737**	0.0113
8	3-min Burpee test [number of cycles]	**-0.1991**	**-0,1291**	**-0.1122**
9	12-minute rowing ergometer test [m]	**-0.2445**	**0.1267**	**-0.2962**
10	30-s sit-ups [number of sit-ups]	**-0.1573**	**0.1788**	**-0.2452**
11	Medicine ball backward throw [cm]	**0.0459**	**0.1868**	**-0.0688**
12	Medicine ball forward throw [cm]	0.0028	**0.2139**	**-0.1262**
13	Flexed arm hang [s]	**-0.0535**	**0.0725**	**-0.0868**

Note: Values in bold denote significant correlations at α=0.05

In women, the highest values of the correlation coefficient were observed between body height and the results of the following trials: standing long jump (*r*=0.31), 8-s SHC test (*r*=0.27) and medicine ball forward throw (*r*=0.21).Body height was also positively correlated with the following motor tests: downward bend from standing position, standing long jump, 8-s SHC, downward bend from standing position, 12-minute rowing ergometer trail, 30-s sit-ups, medicine backward throw, and flexed arm hang. Body height was negatively correlated with the remaining tests. All motor tests (excluding medicine ball backward and forward throws) were significantly negatively correlatedwith body mass, in particular in endurance and strength endurance trials (*r* = -0.24, -0.22, -0.20), but also in the 8-s SHC test (r = -0.21). Similar to body mass, BMI was significantly negatively correlated with all motor tests,excluding 1-MBT (Table 2).

Table 3. Correlations between anthropometric parameters and motor abilities in men (N=2691)

No	Motor test	Body Mass	Body height	BMI
1	Standing long jump [cm]	**-0.0973**	**0.1504**	**-0.1898**
2	8-s SHC [number of claps]	**-0.0958**	-0.0243	**-0.0934**
3	4×10 m shuttle run [s]*	**-0.5739**	**0.2701**	**0.4719**
4	Zig-zag run [s]*	**-0.3333**	**0.0867**	**0.3135**
5	Downward bend from standing position [cm]	**-0.1833**	**-0.0786**	**-0.1578**
6	Barbell overhead trunk rotation [cm]*	**-0.0544**	0.0373	**-0.0918**
7	1-min Burpee Test [number of cycles]	**-0.1613**	0.0451	**-0.1507**
8	3-min Burpee test [number of cycles]	**-0.1256**	0.0002	**-0.1351**
9	12-minute rowing ergometer test [m]	**-0.0578**	0.0223	**-0.0745**
10	30-s sit-ups [number of sit-ups]	**-0.0662**	0.0379	**-0.0954**
11	Medicine ball backward throw [cm]	**0.0757**	**0.1642**	-0.0151
12	Medicine ball forward throw [cm]	**0.0465**	**0.0801**	0.0000
13	Chest-to-bar pull-ups [number of pull-ups]	**-0.1076**	0.0113	**-0.1254**

Note: Values in bold denote significant correlations at α=0.05

Comparableto women, the vast majority of motor abilities in men were significantly negatively correlated withbody mass, excluding medicine ball backward and forward throws (Table 3). Body height was bound by positive correlations with motor trials,including standing long jump, 4×10 m shuttle run, zig-zag run, and medicine ball backward and forward throws. Flexibility, measured in the downward bend from a standing position, was significantly negatively correlated only with body height. The strongest, significant, positive correlations were observed between body height and the following trials: 4×10 m shuttle run (r=0.27), medicine ball backward throw (r = 0.16), and standing long jump (r = 0.15), although the values of the correlation coefficient were not as high as in women. Concomitantto body mass, BMI was significantly negatively correlated with the vast majority of motor abilities,excluding speed/agility trials (4×10 m shuttle run – 0.47, and zig-zag run – 0.31). No significant differences were observed between BMI and medicine ball backward and forward throws (Table 3).

On the whole, the mutual relationships between the results of the conducted trials (Table 4) were consistent with expectations, but the specific character of the noted correlations was somewhat different for women and men.

Table 4. Analysis of correlations between the motor abilities of men and women

Women / Men	Number of test												
	1	2	3	4	5	6	7	8	9	10	11	12	13
(1) Standing long jump	-	**0.2519**	**0.4520**	**0.3292**	**0.1392**	0.0265	0.0224	**0.0568**	**0.0977**	**0.1977**	**0.2132**	**0.1652**	**0.1422**
(2) 8-s SHC	**0.1196**	-	**0.2589**	**0.2133**	**0.2818**	**-0.1518**	**0.2119**	**0.2543**	**0.3467**	**0.3572**	**0.1527**	**0.1936**	**0.1711**
(3) 4×10 shuttle run	**0.2984**	**0.2364**	-	**0.4639**	**-0.0643**	-0.0295	**-0.1711**	**-0.1861**	**-0.1962**	**-0.2124**	**-0.0426**	**-0.0660**	**-0.1159**
(4) Zig-zag run	**0.2151**	**0.2283**	**0.3768**	-	-0.0130	-0.0133	**-0.0416**	**-0.0444**	**-0.1261**	**-0.2034**	**0.0499**	**-0.0967**	**-0.0891**
(5) Forward bend	**0.1604**	**0.0517**	**0.1323**	**0.0936**	-	**-0.0779**	**0.1304**	**0.1206**	**0.1332**	**0.1606**	**0.2135**	**0.2264**	**0.1162**
(6) Barbell trunk rotation	0.0020	-0.0365	**0.2095**	**0.2783**	**0.0691**	-	0.0223	0.0200	-0.0269	-0.0210	0.0004	**-0.0863**	-0.0282
(7) 1-MBT	**0.2155**	0.0433	-0.0057	0.0119	0.0408	-0.0353	-	**0.7004**	**0.4595**	**0.1949**	0.0296	**0.0736**	-0.0073
(8) 3-MBT	**0.2767**	**0.0973**	-0.0328	**-0.0654**	**0.0580**	**-0.1132**	**0.4412**	-	**0.6794**	**0.1115**	0.0187	0.0302	**0.0593**
(9) 12-min ergometer	**0.1738**	0.0103	-0.0101	0.0060	0.0321	**-0.1220**	**0.3355**	**0.6987**	-	**0.1878**	**0.0600**	**0.0892**	**0.0505**
(10) Sit-ups	**0.1595**	-0.0256	**-0.0881**	**-0.1195**	**-0.0473**	**-0.0761**	**0.1671**	**0.1436**	**0.0904**	-	**0.0773**	**0.1807**	**0.0814**
(11) Ball backward throw	**0.3443**	0.0129	**-0.2426**	0.0133	**0.0636**	**0.1388**	**0.1283**	**0.1226**	-0.0100	-0.0155	-	**0.4809**	**0.1217**
(12) Ball forward throw	**0.2148**	0.0212	**-0.1602**	-0.0438	**0.0762**	**0.0676**	**0.1175**	**0.1838**	0.0310	0.0343	**0.4910**	-	**0.0839**
(13) Pull-ups/hang on bar*	**0.3282**	0.0423	**-0.0582**	**-0.1026**	**0.2531**	-0.0106	**0.1405**	**0.1947**	**0.0913**	**0.1365**	**0.3001**	**0.1316**	-

Note: Values in bold denote significant correlations at α=0.05

In women, the strongest positive correlations were observed between endurance and strength endurance tests: 1-MBT, 3-MBTand 12-minuterowing ergometer test (0.70, 0.68, 0.46, respectively). Similar trends were noted in men, although the relevant correlations were somewhat weaker (0.70, 0.44, 0.34, respectively). In both sexes, significant and relatively strong correlations were also observed between strength tests, such as medicine ball backward and forward throws (women – 0.48, men – 0.49), and in men, also in the flexed arm hang on bar (0.30). In speed/agility tests, the strongest correlations were noted in the 4×10 m shuttle run and the zig-zag run (women – 0.46, men – 0.37). In both sexes, positive correlations were also determined between speed/agility tests, including 8-s SHC, 4x10 m shuttle run and the zig-zag run (women – 0.26, 0.21, 0.46; men – 0.24, 0.23, 0.38) and standing long jump (women – 0.25, 0.45, 0.33; men – 0.12, 0.30, 0.22). In women, the 8-s SHC test was significantly correlated (negatively in one case) with the remaining motor tests. In men, the standing long jump test was significantly and only positively correlated with the highest number of the remaining tests (no significant correlations with the barbell overhead trunk rotation) (Table 4).

Discussion

The observed correlations between anthropometric characteristics and motor abilities of first-year female and male university students are consistent with the results of research studies cited in the introduction of the present study. Anthropometric characteristics (height, body mass, BMI) were significantly higher in male than in female participants. As expected, body mass and BMI exerted a negative influence on most motor abilities, excluding selected strength trials, such as medicine ball backward and forward throws. Body mass and BMI were positively correlated with strength abilities in a study comparing physical fitness levels in preschoolers, primary school students, female university students (FUS) and early education teachers (EET) (Podstawski,Mańkowski, &Raczkowski, 2014). Both FUS and EET received significantly higher scores in the medicine ball throw than the evaluated children, which can be attributed to higher values of body mass, height and BMI. However, these parameters exerted a negative influence on the number of completed cycles in the 3-MBT (strength endurance test) (Podstawski et al., 2014). The above correlations are clearly manifested in throwing sports (discus, hammer and push ball), where the best throwers are characterized by high body mass (in particular muscle mass) and height (Pavlović, 2019). A study evaluating the correlations between body fat and motor fitness in 14 female and 14 male students of a liberal arts university in the Southwest United States revealed that submaximal VO_2 was significantly negatively correlated (-0.66, $p<0.01$) with body fat and significantly positively correlated (0.39, $p<0.05$) with push-ups (Busing & West, 2016). Significant correlations were also reported between the sit-and-reach flexibility test and push-ups (0.588,$p<0.01$), and between push-ups and partial curl-ups (0.457, $p<0.05$). Body fat was significantly negatively correlated (-0.408, $p<0.05$) with push-ups. In the cited study, men were characterized by significantly higher($p<0.00$, F=88.33) values of submaximal VO_2 (62.60 and 40.58 l/min/kg, respectively) and performed a significantly higher ($p<0.00$, F=21.76) number of push-ups (29.71) then women (13.64). Body fat values were significantly higher ($p<0.00$, F=31.91) in women than in men (28.68% and 13.86%, respectively) (Busing & West, 2016). Body mass and BMI were negatively correlated with the endurance-strength abilities of female students performing the 3-MBT (Podstawski,Markowski, Choszcz, &Żurek, 2016a). Similar correlations were also reported in studies evaluating the performance of women and men in 500-meter (Choszcz,Podstawski, &Wysocka-Welanc, 2009; Podstawski,Choszcz, Konopka, Klimczak, &Starczewski, 2014) and 1000-meter rowing ergometer tests (Podstawski,Choszcz, Siemianowska, &Skibniewska, 2012). Somatic features (body mass, height, BMI) also exerted a negative impact on the results of speed tests, such as the 8-s SHC test (Podstawski,Mańkowski, Omelan, &Choszcz, 2016). Significant ($p<0.05$) correlations between physical fitness, body composition and anthropometry were found among Iranian female university students performing various trails (sit-ups, flexibility test, Sargent jump test, 4 x 9 m run, 540 m run, push-ups) of the AAHPERD test (Mohammadi&Saberi, 2016). The cited study demonstrated that BMI, WHR and percent body fat correlate negatively with physical fitness.

Pribis et al. (2010) investigated the correlations between the physical fitness levels of university students and their BMI and body fat between 1996-2008. The average fitness levels declined with a decrease in VO_{2max}($p<0.01$ for both sexes)and an increase in % body fat in both sexes (0.513%/year for males and 0.654%/year for females. The study revealed a significant indirect correlation between VO_{2max} levels and % body fat($r= -0.49$; $p<0.01$ for males; $r=-0.42$, $p< 0.01$ for females) (Pribis et al., 2010).

In the present study, an analysis of motor abilities revealed the highest values of the sexual dimorphism index and the greatest percentage differences (in favor of male students) were noted in endurance and strength trials, particularly in the 12-minute rowing ergometer test, standing long jump and medicine ball backward and forward throws, whereas significantly smaller variations were observed in speed/agility tests and flexibility tests. On average, male students scored 32.17% higher in strength tests (standing long jump, 30-s sit-ups, medicine ball backward and forward throws), 22.04% lower in endurance tests (12-minute rowing ergometer test, 1-MBT and 3-MBT), 15.9% higher in speed/agility tests (8-s SHC, 4x10 m shuttle run, zig-zag run), and 15% lower in flexibility tests (downward bend from standing position, barbell overhead trunk rotation) than female participants. Coast et al. (2004), Courtright,McCormnick, Postlethwaite, Reeves, &Mount (2013)and Ployhart, et al. (2006) also demonstrated that males scored substantially better on muscular strength and cardiovascular endurance tests. Similar results were reported in an international study aiming to develop classification standards for endurance-strength abilities based on the 3-MBT (Podstawski et al., 2019). Sex differences are less pronouncedwith regard to muscular strength, and sex differences in muscular strength vary considerably across different body regions. Proper training has been reported to elicit agreater increase in male vs.female performance during both muscular and strength tests, and shown to exacerbate male-female differences in cardiovascular endurance(Courtright et al., 2013; Ployhart et al., 2006). According to Glenmark (1994), sex differences in strength and endurance abilities (based on the results of the 9-minute running test, Sargent jump, handgrip test, and two-hand lift test) change between the ages of 16 and 27 years, which leads tochanges in the relative proportions of type I and II fibers.In subjects aged up to 27 years, the proportion of type I fibers increased in women and decreased in men, which could be associated with changes in the type of undertaken physical activities from speed and strength-building activities to more endurance demanding activities, as well as an increase in VO_{2max} values in women. Studies performed on seniors (Liang & Cameron-Chumlea, 1998) and adults with Down's syndrome (Terblanche & Boer, 2013) also revealed higher values of muscular strength, postural balance, coordination and endurance in men than in women. Slovak male university students performed significantly better in Eurofit battery tests (sit-and-reach, standing long jump, medicine ball throw, 10×5 m shuttle run, 30-s sit-ups, endurance shuttle run) than female students (Pistlova,Balint, &Sedlacek, 2014). Similar results were reported by Coksevim and Caksen (2005). In a study evaluating sex-specific differences in motor speed (finger tapping test) and eye-hand coordination (grooved pegboard test), men generally performed better than women, excluding in the pegboard non-dominant hand test (Ruff & Parker, 1993). In a factor analysis study, different factor loadings were reported in men and women performing the finger tapping test and the grooved pegboard tests (Baser & Ruff, 1987).

In the current study, an analysis of the correlations between different motor tests produced interesting observations. The tests evaluating specific motor abilities (speed/agility, strength, endurance) were bound by significant correlations with other motor tests in both sexes (Table 4). These results are indicative of concurrent validity, which confirms the validity of new tests for measuring the analyzed parameters based on the correlations with other tests whose validity has been previously confirmed and accepted in the scientific community. In this study, the new tests that were bound by significant correlations with the remaining tests were the 3-MBT and 8-s SHC.

The observed correlations (Tables 1 and 2) point to the risks associated with low levels of physical activity among university students who are classified as physically inactive in the literature (Podstawski, 2013; Podstawski et al., 2014). University years are characterized by rapid reduction in physical activity (ACHA-NCHA, 2006; Bray & Born, 2004; Grubbs & Carter 1995; Pribis et al., 2010) and the beginning of a sedentary lifestyle (Pinto & Marcus, 1995). Physical function and mobility are often restricted in students with high body mass and high BMI, and these individuals are more likely to opt for less intense forms of physical exercise that are not sufficient to increase/maintain adequate fitness levels, which contributes to a further increase in body mass and body fat (Podstawski et al., 2015; Podstawski,Markowski, Choszcz, Lipiński, &Borysławski, 2017). This represents a negative spiral, and can be observed in the prevalence of obesity which has tripled among adolescents in the past three decades in most developed and developing countries (Garcia-Pastor,Salinero, Sanz-Frias, Petrusa, & Del Coso, 2016; ZanovecLakkakula, Johnson, &Turri, 2009). The transition from secondary school to universityis a critical period for the development of obesity due to lower levels of physical activity among university students (Leslie,Fotheringham, Owen, & Bauman, 2001; Irwin, 2004).

Limitations

It can be assumed that intermediate endurance tests concurrentlymeasure the level of strength endurance, also referred to as endurance-strength abilities (Podstawski et al., 2014;PodstawskiMarkowski P., Choszcz D., Klimczak J., Romero Ramos O., & Merino Marban, 2016b;Podstawskiet al., 2016a), which is directly linked with spatiotemporal structure. The rowing ergometer test (Mikulić, 2008), 1-MBT and 3-MBT (Podstawski et al., 2016) favor individuals with greater muscular development, skeletal robustness, and lower body fat (for overcoming water resistance in the rowing ergometer test) and lower body mass (higher number of cycles in Burpee tests). The 12-minute Cooper test is conceivablymore appropriate for evaluating endurance abilities, but it could not be conducted in this study due to adverse weather conditions.

Conclusions

Male university students were characterized by significantly higher body mass, height, and BMI than female students. In terms of motor fitness, the greatest sex-related differences were noted in endurance and strength abilities (in favor of men); whereas only minor differences in speed/agility abilities were notedbetween the sexes, whilst female participants were more flexible than men. Body mass was significantly negatively correlated with all motor tests, excluding medicine ball backward and forward throws (positive correlation). Significant positive correlations were observed between motor tests evaluating the same motor abilities.

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Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

American College Health Association. American College Health Association-National College Health Assessment (ACHA-NCHA). (2006). Spring 2005 Reference Group Data Report (Abridged). *JAm Col Health*, 55, 5-16.

Astrand, P. T. E. (1953). *Experimental Studies of Physical Working Capacity in Relation to Sex and Age*. Copenhagen: E. Munksgaard.

Astrand, P. T. E, & Rodahl, K. (1986). *Textbook of work physiology*. New York: McGraw-Hill.

Baser, C. N.& Ruff, R. M. (1987). Construct validity of the San Diego Neuropsychological Test Battery. *Arch ClinNeur*, 2, 13-32.

Benefice, E., Fouere, T., &Malina, R. M. (1999). Early nutritional history and motor performance of Senegalese children, 4-6 years of age. *Ann Hum Biol*, 26, 443-455.

Bolonchuk, W.W., Siders, W.A., Lykken, G.I., &Lukaski, H.C. (2000). Association of dominant somatotype of men with body structure, function during exercise, and nutritional assessment. *Am J Hum Biol*, 12, 167-180.

Branta, C. J., Haubenstricker J., &Seefeldt, V. (1984). Age changes in motor skill during childhood and adolescence. *Exerc Sport Sci Rev*, 12, 467-520.

Bray, S.R.,&Born, H.A. (2004). Transition to university and vigorous physical activity: implications for health and psychological well-being during transition to university life. *J Am Coll Health*, 52, 181-188.

Busing, K., &West, C. (2016). Determining the relationships between physical fitness, gender, and life satisfaction. *SAGE Open*, 1-5, Retrieved from: https://doi.org/10.1177/2158244016669974

Carter, J. E. L. (1970). The somatotype of athletes – a review. *Hum Biol*, 42, 535-569.

Choszcz, D., Podstawski, R., &Wysocka-Welanc, M. (2009).Measurements of motor fitness of students using the rowing ergometer.*Hum Mov*, 10(1), 46-52.

Coast, J. R. , Blevins, J. S., &Wilson, B. A. (2004). Do gender differences in running performance disappear with distance?*Can JAppl Physiol*, 29(2), 139–145.

Coksevim, B., &Kaksen H. (2005). Evaluation of exercise performance in healthy Turkish adolescents. *Int J Neurosci*, 115, 1033–1039.

Courtright, S. H., McCormnick, B. W., Postlethwaite, B. E., Reeves, C. J., &Mount, M. K. (2013). A meta-analysis of sex differences in physical ability: Revised estimates and strategies for reducing differences in selection contexts. *Appl Psychol*, 98(4), 623-641.

Cozens, F. W. (1930). A study of stature in relation to physical performance. *Res Quart*, 1, 38-45.

Cureton, T. K. (1941). Body build as a framework of reference for interpreting physical fitness and athletic performance. *Res Quart*, 12 (Suppl.), 302-330.

De Garay, A. L., Levine, L., &Carter, J. E. L. (1974). *Genetic and anthropological studies of Olympic athletes performance*. New York: Academic Press.

De Moor, M. H. M., Spector T. D., Cherkas L. F., Falchi M., Hottenga J. J., Boomsma D. I., & de Geus E. J. C. (2007). Genome-wide linkage scan for athlete status in 700 British female DZ twin pairs. *Twin Res Hum Gen*, 10(6), 812-820.

DeOreo, K., &Keogh, J. (1980). *Performance in fundamental motor tasks*. In C. B. Corbin (Ed.), A *Texbook of Motor Development* (pp. 34-56). Dubuque, IA: Brown.

Espenschade, A. S., &Eckert, H. M. (1980). *Motor Development* (2nd ed.). Columbus, OH: Merill.

Fortney, V. L. (1983). The kinematics and kinetics of the running pattern of two-, four-, and six-year-old children. *Res Quart Exerc Sport*, 54, 126-135.

Frandkin, A.J.,Zazryn, T.R.,&Smoliga, J.M. (2010). Effects of warming-up on physical performance: A systematic review with meta-analysis. *J Strength Cond Res*, 24(1), 140-148.

Garcia-Pastor, T., Salinero, J. J., Sanz-Frias, D., Petrusa, G., &Del Coso, J. (2016). Body fat percentage is more associated with low physical fitness than with sedentarism and diet in male and female adolescents.*PhysiolBehav*, 165, 166-172.

Gebhardt, D. L., & Baker, T. A. (2010). *Physical performance*. In J. C. Scott & D. H. Reynolds (Eds.).*Handbook of workplace assessment* (pp. 165–197).San Francisco, CA: Jossey–Bass.

Glenmark, B. (1994). Skeletal muscle fibre types, physical performance, physical activity and attitude to physical activity in women and men. A follow-up from age 16 to 27. *Acta PhysiolScand*, 623 (Suppl), 1-47.

Gronek, P., Gronek, J., Lulińska-Kuklik, E., Spieszny, M., Niewczas, M., Kaczmarczyk, M., Petr, M., Fischerova, P., AhmetovIldus, I., &Żmijewski, P. (2018). Polygenic Study of Endurance-Associated Genetic Markers NOS3 (Glu298Asp), BDKRB2 (-9/+9), UCP2 (Ala55Val), AMPD1 (Gln45Ter) and ACE (I/D) in Polish Male Half Marathoners. *J Hum Kinet*, 64(1), 87-98.

Grubbs, L.,&Carter, J. (2002). The relationship of perceived benefits and barriers to reported exercise behaviours in college undergraduates. *Fam Community Health*, 25, 76-84.

Hales, C. M., Carroll, M. D., Fryar, Ch.D., &Ogden, C. L. (2017). Prevalence of Obesity among adults and youth: united states, 2015-2016. *National Center for Health Statistics Data Brief*, 288, 1-8.

Halverson, L. E., Roberton, M. A., &Langerdorfer, S. (1982). Development of the overarm throw: movement and ball velocity changes by seventh grade. *Res Quart Exerc Sport*, 53, 198-205.

Hasley, L. D., East, W. B., &Stillwell, J. M. (1982). Body fatness and motor performance.*Res Quart Exerc Sport*, 53, 133-140.

Irwin, J. D. (2004). Prevalence of university students' sufficient physical activity: A systematic review. *Percept Motor Skill*, 98 (3 Pt 1), 927-943.

Jaskólski, A, &Jaskólska, A. (2016). Podstawyfizjologiiwysiłkufizycznego z zarysemfizjologiiczłowieka [The physiology of physical exertion and an outline of human physiology]. Wrocław: AWF.

Jaworski, J. (2005). The level and dimorphism of selected motoric abilities in children aged 7 to 15 living in the country with environmental influences taken into account. *AUMC-S Lublin – Polonia (Sectio D)*, LX(162), Suppl. XVI: 241-245.

Karpowicz, K., Krych, K., Karpowicz, M.,&Gronek,P. (2018). The relationship between CA repeat polymorphism of the IGF-1 gene and the structure of motor skills in young athletes. *Acta Biochim Pol*, 65(1), 43-50.

Kolokoltsev, M. M., Iermakov S. S., &Jagiello,M. (2018). Physical condition of female students with different level of body mass deficiency. *PES*, 22(2), 63-69. doi:10.15561/20755279.2018.0202.

Kozina, Z, Iermakov, S, Cretu, M., Kadutskaya, L, &Sobyanin, F. (2017). Physiological and subjective indicators of reaction to physical load of female basketball players with different game roles. *JPES*, 17(1), 1428–1432.

Kozina, Z.L., Iermakov, S.S., Kadutskaya, L.A., Sobyanin, F.I., Krzeminsk, M., Sobko, I.N., &Ryepko, O.A. (2016). Comparative characteristic of correlation between pulse subjective indicators of girl students' and school girls' reaction to physical load. *PES*, 20(4), 24-34.

Kubaisy, W. Al., Mohamad, M., Ismail, Z., & Abdullah, N. N. (2015). Gender differences: motivations for performing physical exercise among adults in Shah Alam. Procedia - *Soc Behav Sci*, 202, 522-530.

Leslie, E, Fotheringham, M, Owen, N, &Bauman, A. (2001). Age-related differences in physical activity levels of young adults. *MedSciSportExerc*, 33(2), 255-258.

Liang, M.T., &Cameron-Chumlea, W.M. (1998). Balance and strength of elderly Chinese men and women. *J Nutr Health Aging*, 2(1), 21-27.

Linde, R. S., Metter, E. J., Lynch, N.A., Fleg, J. L., Fozard, J. L., Tobin, J., Roy, T. A., &Hurley, B. F. (1997). Age and gender comparisons of muscle strength in 654 women and men aged 20-93 yr. *J Appl Physiol*, 83(5), 1581-1587.

Malina, R. M. (1975). Anthropometric correlates of strength and motor performance. *Exerc Sport Sci Rev*, 3, 249-274.

Malina, R. M., & Bouchard, C. (1991). *Growth, Maturation, and Physical Activity*. Champaign, IL: Human Kinetics.

Mikolajczyk, R. T., Maxwell, A. E., Ansari, W. El, Stock, Ch., Petkeviciene, J., &Guillen-Grima, F. (2010). Relationship between perceived body weight and body mass index on self- reported height and weight among university students: a cross-sectional study in seven European countries.*BMC Public Health*, 10, 40. Retrieved: http://www.biomedcentral.com.1471-2458/10/40.

Mikulić, P. (2008). Anthropometric and physiological profiles of rowers of varying ages and ranks. - *Kinesiology*, 40(1), 80-88. -

Milanese, Ch., Bortolami, O., Bertucco, M., Verlato, G., &Zancanaro, C. (2010). Anthropometry and motor fitness in children 6-12 years. *JHSE*, 5(2), 265-279.

Milne, C., Seefeldt, V.,&Reuchlein, P. (1976). Relationship between grade, sex, race, and motor - performance in young children. *Res Quart*, 47, 726-730. -

Mohammadi, E., &Saberi, A. (2016). The relationship between body composition, anthropometry, and physical fitness in female university students. *TSS*, 3(23), 155-158.

Nelson, J. K., Thomas, J. R., Nelson, K. R., &Abraham, P. C. (1986). Gender differences in children's throwing performance: biology and environment. *Res Quart Exerc Sport*, 57, 280-287.

Pavlović, R. (2019). The differences of some anthropometrics and kinematic parameters in shot put finalists World championship in athletics (Berlin, 2009- Daegu 2011). *JASPE*, 2(1), 5-14.

Peltzer, K., Pengpid, S., Samuels, T.A., Özcan, N.K., Mantilla, C., Rahamefy, O.H., Wong, M.L., &Gasparishvili A. (2014). Prevalence of overweight/obesity and its associated factors among university students from 22 countries. *IntJ Environ Res Public Health*, 11, 7425-7441.

Pinto, B.M.,&Marcus, B.H. (1995). A stage of change approach to understanding college students' physical activity. Journal of American College Health, 44, 27-31.

Pistlova, L., Balint, G., &Sedlacek, J. (2014). Physical development and general motor performance of Bratislava university students. *Procedia – Social and Behavioral Sciences*, 117, 741-747.

Ployhart, R. E., Schneider, B., & Schmitt, N. (2006). *Staffing organizations: Contemporary practice and theory (3rd ed.)*. Mahwah, NJ: Erlbaum.

Podstawski, R. (2013). Secular trends in anaerobic fitness test performance of physically inactive young males (2000-2006). *JPES*, 13(1), 73-77.

Podstawski, R., &Borysławski, H. (2012). Relationships between selected anthropometric features and motor abilities of children aged 7 – 9. *Clin Kinesiol*, 66(4), 82-90.

Podstawski, R., Choszcz, D., Siemianowska, E., &Skibniewska, K.A. (2012). Determining the effect of selected anthropometric parameters on the time needed to cover 1000 m on a rowing ergometer by physically inactive young women. *Isokinet Exerc Sci*,20, 197-204.

Podstawski, R., Mańkowski, S., Omelan, A., &Choszcz, D. (2016). Relationships between somatic features, speed abilities and changes in heart rate following short-term physical activity in young women and men. *Roczniki Naukowe WSWFiT*, 3(17), 19-27. (English abstract).

Podstawski, R., Mańkowski, S., &Raczkowski, M. (2014). The level of strength and endurance-strength abilities of the female early education teachers as examined by the Medicine Ball Forward Throw and the 3 Minute Burpee test: a comparative analysis. *LASE Journal of Sport Science*, 5(2), 93-109.

Podstawski, R.,Markowski, P., Clark, C. C. T., Choszcz, D., Ihász, F.,Stojiljković, S., Gronek P. (2019). International standards for the 3-Minute Burpee Test: high-intensity motor performance. *J Hum Kinet*, DOI: 10.2478/hukin-2019-0021.

Podstawski, R., Markowski, P.,·Choszcz, D.,·&Klimczak, D.·(2015). *Anthropometric indicators and motor abilities of university students performing various types of physical activities (martial arts, volleyball,bodybuilding/fitness, jogging followed by sauna, golf, general PE classes)*. In R. M. Kalina(ed.),*Archives of Budo Conference Proceedings: Health and Martial Arts in Interdisciplinary Approach*(pp. 139-148), Częstochowa.

Podstawski, R., Markowski, P., Choszcz, D., Klimczak, J., Romero Ramos, O., &Merino Marban, R. (2016a). Methodological aspect of evaluation of the reliability the 3-Minute Burpee Test. *Arch Budo Sci Martial Arts Extreme Sport*, 12, 137-144.

Podstawski, R., Markowski, P., Choszcz, D., Lipiński, A., &Borysławski, K. (2017). Effectiveness of Martial Arts training vs. other types of physical activity: Differences in body height, body mass and motor abilities. *SAJRSPER*, 39(1), 111-133.

Podstawski, R., Markowski, P., Choszcz, D., &Żurek, P. (2016a). Correlations between anthropometric indicators, heartrate and endurance-strength abilities during high-intensity exercise of young women. *Arch Budo Sci Martial Arts Extreme Sport*, 12, 17-24.

Podstawski, R., Choszcz, D., Konopka, S., Klimczak, J., &Starczewski, M. (2014). Anthropometric determinants of rowing ergometer performance in physically inactive collegiate females. *Biol Sport*, 31(4), 315-321.

Pribis, P., Burtnack, C.A., McKenzie, S.O., &Thayer, J. (2010). Trends in body fat, body mass index and physical fitness among male and female college students. *Nutrients*, 2, 1075-1085; doi: 10.3390/nu2101075.

Raudsepp, L., &Pääsuke, M. (1995). Gender differences in fundamental movement patterns, motor - performance and strength measurements of pubertal children. *PediatrExerc Sci*, 7, 294-304. -

Roberton, M. A., Halverson, L. E., Landergorfer, S., &Williams, K. (1979). Longitudinal changes min children's overarm throw ball velocities. *Res Quart*, 50, 256-264.

Ruff, R.M., &Parker, S.B. (1993). Gender and age -specific changes in motor speed and eye-hand coordination in adults: normative values for the Finger Tapping and Grooved Pegboard tests. *Percept Motor Skill*, 76, 1219-1230.

Sackett, P. R., & Wilk, S. L. (1994). Within-group norming and other forms of score adjustment in preemployment testing. *Am Psychologist*, 49, 929-954. doi:10.1037/0003-066X.49.11.929

Siders, W. A., Lukaski, H. C., &Bolonchuk, W. W. (1993). Relationships among swimming performance, body composition and somatotype in competitive collegiate swimmers. *J Sport Med Phys Fit*, 33(2), 166-171.

Sills, F. D. (1950). A factor analysis of somatotypes and their relationship to achievement in motor skills. *Res Quart*, 21, 424-427.

Sills, F. D. &Michem, J. (1957). Prediction of performance on physical fitness tests by means of somatotype ratings.*Res Quart*, 28, 64-71.

Sparling, P. B. (1980). A meta- analysis of studies comparing maximal oxygen uptake in men and woman. *Res Quart ExercSport*, 51(3), 542-552.

Sullivan, M. J., Cobb, F. R., &Higginbotham, M. B. (1991). Stroke volume increases by similar mechanisms during upright exercise in normal men and women. *Am J Cardiol*, 67, 1405-1412.

Szalata, M., Słomski, R., Balko, S., &Balko, I. (2019). Advances in athlete genomics in 2019; short review. *TSS*, 2(26), 57-62.

Tanner, J. M. (1964). The physique of the Olympic athlete. London: George Allen and Unwin.

Tanner, J.M., Israelson, W. J., & Whitehouse, R. H. (1960). Physique and body composition as factors affecting success in different athletic events. *J Sport Med Phys Fit*, 14, 397-411.

Terblanche, E., &Boer, P. -H. (2013). The functional fitness capacity of adults with down syndrome in South Africa. *J IntellDisabil Res*, 57(9), 826-836.

Thomas, J. R., &French, K. E. (1985). Gender differences across age in motor performance: meta-analysis. *Psychological Bulletin*, 98(2), 260-282.

United States Department of Health and Human Services. (2008). *The 2008 activity guidelines for Americans*. Washington, DC: U.SA.

Wells, C. I., &Plowman, S. A. (1983). Sexual differences in athletic performance: Biological or behavioral? *The Physician and Sportsmedicine*, 11(8), 52-63.

Zanovec, M., Lakkakula, A. P., Johnson, L. G., &Turri, G. (2009). Physical Activity is Associated with Percent Body Fat and Body Composition but not Body Mass Index in White and Black College *Students.Int JExerc Sci*, 2(3), 175-185.