Sex differences in anthropometric characteristics and a decrease in power during the 3-minute Burpee test: a relative assessment

Authors' Contribution:
- **A** Study Design
- **B** Data Collection
- **C** Statistical Analysis
- **D** Manuscript Preparation
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Abstract

Background & Study Aim: Anaerobic capacity is defined by the power generated during short-term exercise performed at the maximum intensity or the total work performed during the test. Most tests involve rowing ergometer training, stair climbing tests and repetitive jump tests on a dynamographic platform. The aim of the study was knowledge about sex differences in anthropometric traits, motor performance, and a decrease in power among university students performing extremely strenuous exercise during the 3-Minute Burpee Test (3-MBT).

Material & Methods: The study involved 163 men and 196 women aged 19-22 (mean age 20.4 ±0.67 and 20.4 ±0.65 years, respectively) characterized by moderate levels of physical activity (mean: 1,148 and 998 METs, respectively). The participants' body mass and height were measured, and the results were used to calculate their BMI scores. Endurance-strength abilities were evaluated during the 3-MBT. Sex differences in anthropometric characteristics and motor performance were examined by calculating the sexual dimorphism (SD_{Index}) indicator.

Results: The values of anthropometric traits were significantly ($p<0.001$) higher in men than in women. The number of cycles completed by both sexes decreased significantly in successive minutes of the 3-MBT, but motor performance levels were higher ($p<0.001$) in men than in women (55.0 ±10.97 vs 46.7 ±9.39 cycles/min) in all cases. Sexual dimorphism in endurance-strength abilities was most pronounced in the second minute (SD_{Index} = 7.8) and least pronounced in the first minute of the test (SD_{Index} = 5.9). The decrease in power was greater in women (14.0%) than in men (12.3%).

Conclusions: Men are characterized by significantly higher values of anthropometric characteristics and endurance-strength abilities than women. In extremely strenuous exercise performed by persons with moderate levels of physical activity (PA), the deascrease in power is significantly greater in women than in men. These observations suggest the PA levels of female and male participants should be examined in greater detail before evaluations of sexual dimorphism in power generation and power decline during the 3-MBT.

Keywords: extreme efforts • load • maximal power • men • motor performance • university students • women

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Ethical approval: The study was approved by the Bioethical Committee and the authorities of the University of Warmia and Mazury in Olsztyn, Poland

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3-MBT – The 3-Minute Burpee Test for evaluating endurance-strength abilities [11].

MET – Metabolic Equivalent of Task [19].

Sexual dimorphism – somatic and motor differences between women and men which influence their physical abilities.

Physical activity – *noun* exercise and general movement that a person carries out as part of their day [35].

Load – *noun* **1.** a weight or mass which is supported **2.** the force that a body part or structure is subjected to when it resists externally applied forces **3.** the amount of something, usually weight, that a body part can deal with at one time [35].

Motor – *adjective* relating to muscle activity, especially voluntary muscle activity, and the consequent body movements [35].

Performance – *noun* the level at which a player or athlete is carrying out their activity, either in relation to others or in relation to personal goals or standards [35].

INTRODUCTION

Anaerobic capacity is defined by the power generated during short-term exercise performed at the maximum intensity or the total work performed during the test. Most tests involve rowing ergometer training (such as the Wingate test), stair climbing tests (such as the Margaria-Kalamen test) and repetitive jump tests on a dynamographic platform (such as the Bosco test) [1]. In these trials, anaerobic capacity is determined mainly based on the highest generated power. At present, anaerobic capacity is most frequently evaluated in the Wingate test, which is also known as the Bar-Or test based on the name of its inventor [2]. The Wingate test is performed on a stationary bicycle for 30 seconds to measure peak anaerobic power and capacity (usually with a load corresponding to 7.5% of body mass) at a given resistance [3].

In aerobic exercise, the maximum oxygen uptake is the most accurate criterion for evaluating aerobic capacity [4]. The maximum oxygen uptake denotes the highest amount of oxygen consumed during exercise performed at the maximum intensity. Oxygen uptake reaches a maximum level when it does not increase in response to increasing load. In the literature, VO_{2max} values are given in liters per minute [L/min] in evaluations of cardiovascular fitness, and they are expressed per kg of body mass [ml/kg/min] in analyses of the overall fitness level. The values of VO_{2max} can also be assessed in the PWC_{170} Test which is used to predict an athlete's power output in watts [W] on a cycle ergometer at a heart rate of 170 beats per minute [bpm]. In recent years, various modifications have been introduced to tests that measure VO_{2max} uptake, in particular in professional sports training, including in the novel self-paced maximal-oxygen-uptake (VO_{2max}) test (SPV) [5].

The following tests are most widely used for indirect measurements of the maximum oxygen uptake: the Astrand-Ryhming cycle ergometer aerobic test based on the relationship between load, oxygen uptake and heart rate; the Harvard step test which evaluates cardiovascular endurance based on HR during exercise; and the Astrand-Ryhming step test which predicts the maximum oxygen uptake [1]. Field tests such as the Cooper 12-minute run [6] and the 6-minute walk test [7] are also widely used in population studies.

The 3-minute Burpee Test (3-MBT) has been garnering increasing popularity in the scientific community, and its applicability for both functional and athletic training has been recognized in a growing number of Master's theses [8] and scientific articles [9-11]. Despite the above, the 3-MBT has never been used to assess power generation and power decrease during exercise. Burpees gained international attention in 2000, primarily due to CrossFit which revolutionized the fitness world, and they were recognized by other associated training organizations [12]. According to Bingley [8], Kuhn [12] and Podstawski et al. [11], the Burpee is one of the best known exercises worldwide due to its popularity in high intensity interval training programs. Burpees have been used extensively in the military [13, 14] and in combat sports [9, 15] as a superior bodyweight conditioning tool for coaches that has been developed through trial and error.

The spatiotemporal structure of the Burpee and the relevant terminology [8, 12, 16] have evolved considerably since 1939 [17]. Therefore, previous research into the Burpee relied on inconsistent terminology and discrepancies in technical knowledge, which has resulted in uncertain data representation. When performed for more than 3 minutes, this bodyweight movement creates significant physiological stress [14] which is manifested by relatively high heart rate (HR) values [9] and high lactic acid concentrations [8, 10].

The aim of the study was knowledge about sex differences in anthropometric traits, motor performance, and a decrease in power among university students performing extremely strenuous exercise during the 3-Minute Burpee Test (3-MBT).

MATERIAL AND METHODS

Participants

The study involved 359 full-time university students aged 19-22, including 163 males (mean age of 20.4 ±0.67) and 196 females (20.4 ±0.65). To increase the reliability of the results, measurements were conducted in Poland (101 men and 112 women) and Hungary (62 men and 84 women) during physical activity interventions, self-defense classes and obligatory physical education classes (90 minutes per week). Every participant performed the 3-MBT five times during preparatory meetings before the study, to ensure the reliability of measurements [16].

Procedures

The research was performed in observance of the Declaration of Helsinki and upon the prior consent of the Bioethical Committee and the authorities of the University of Warmia and Mazury in Olsztyn. Every participant signed a written consent form before the study.

Measurements

The participants' PA (physical activity) levels were evaluated before the study using the International Physical Activity Questionnaire (Polish short version) [18]. The students were asked to indicate how much exercise (minimum of 10 minute bouts) they had performed in the weeks preceding the study. The associated energy expenditure was calculated and expressed in Metabolic Equivalent of Task (MET) units using the Compendium of Physical Activities [19]. The MET is the ratio of the rate of energy consumed during exercise to the rate of energy consumed at rest. One MET unit denotes the amount of oxygen consumed per minute, which is approximately equal to 3.5 mL/kg/min.

The students were divided into groups with low (L <600 METs-min/week), moderate (M <1500 METs-min/week) and high (H ≥1500 METs-min/week) PA levels. Persons with low PA levels were not included in the study because the 3-MBT is a high-intensity exercise that involves the maximum physical effort. Students performing extracurricular sports and persons with high PA levels could significantly distort the examined relationships; therefore, students enrolled in additional sports as well as students released from physical education classes for medical reasons were also excluded. Only students with moderate PA levels participated in the study.

The results of the IPAQ survey revealed two relatively homogeneous groups of students (female and male) characterized by moderate PA levels. The average PA levels of female and male subjects were calculated based on the respective METs. Body mass and height were measured to the nearest 0.1 mm and 0.1 kg, respectively, on a calibrated WB-150 medical scale with a stadiometer (ZPU Tryb Wag, Poland) and according to standardized guidelines. The results were used to calculate the participants' BMI scores.

Endurance-strength abilities were evaluated based on the number of Burpee cycles completed in 3 minutes [11].

Stage I. Begin in a standing position and move into a supported squat with both hands on the ground.

Stage II. From a supported squat, kick your feet back into a plank with arms extended.

Stage III. Return from the plank position to a supported squat.

Stage IV. Return to a standing position, extend your arms over the head and clap your hands.

The participants repeat the cycle as many times as possible in a given time limit (3 minutes). The number of cycles was measured separately in each minute of the 3-MBT, and the results were recorded in a log that was designed specifically for the study. The values recorded in each minute of the test were then summed up.

Comments: The exercise has to be performed correctly, and the entire cycle has to be completed in the specified order. The plank position should be maintained on extended arms without arching the back, but an exception can be made for individuals without adequate upper body strength. The legs should be fully extended in the plank position. A cycle is not counted when individual stages are not correctly performed.

Statistical analysis

Initially, data were processed in a descriptive statistics module: arithmetic mean, standard deviation (SD or ±), minimum and maximum values. All examined anthropometric features and the results of the 3-MBT had normal distribution; therefore, the Student's *t*-test was used to

compare the relevant values in both sexes. The changes (decrease) in power in successive minutes of exercise were compared separately in men and women by one-way analysis of variance (ANOVA) and the Tukey's Honest Significant Difference test (HSD).

Sex differences in anthropometric characteristics and motor performance were examined by calculating the sexual dimorphism (SD – in this work SD_{Index}) indicator based on the formula proposed by Jaworski [20]:

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

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

Male and female participants did not differ significantly in age, but the values of basic anthropometric traits (body mass, body height, and BMI) were significantly higher (p<0.001) in men (77.6 kg, 179.7 cm, and 24.0 kg/m², respectively) than in women (60.8 kg, 166.6 kg, and 21.9 kg/m²). The highest values of the sexual dimorphism (SD_{Index}) indicator for the evaluated

anthropometric characteristics were noted in body height (SD_{Index}= 2.1) and body mass (SD_{Index} = 1.7), whereas the lowest value was observed in BMI scores (SD_{Index} = 0.77). BMI scores were within the norm in both sexes. Despite the fact that the participants were characterized by moderate PA levels, the average PA levels were significantly higher in men than in women (1,148.0 vs 998.4 MET). Male participants were also characterized by significantly higher (p<0.001) endurance-strength abilities in the first (21.9 vs 19.9 cycles/min), second (17.9 vs 14.8 cycles/min) and third (15.1 vs 12.1 cycles/min) minute of the 3-MBT. Sexual dimorphism in endurance-strength abilities was most pronounced in the second minute (SD_{Index} = 7.8) and least pronounced in the first minute of the test (SD_{Index} = 5.9). The mean value of the SD_{Index} indicator in all samples was determined at 7.7 (Table 1).

The number of cycles completed in successive minutes of the 3-MBT decreased in both groups (Figure 1). The number of cycles completed by male and female participants in the first minute of the test (21.9 and 19.9 cycles/min, respectively) was higher by 4.0 and 5.1 cycles, respectively, than in the second minute, and higher by 6.8 and 7.7 cycles, respectively, than in the third minute (p<0.001). In the second minute of the test (17.9 and 14.8 cycles/min, respectively), male and female students completed 2.8 and 2.5 more cycles, respectively, than in the third minute (p<0.001). The decrease in power during the 3-MBT was higher in female (14.0%) than in male participants (12.3%) (Table 2).

Table 1. Descriptive statistics of the anthropometric characteristics and motor performance of investigated university students in the 3-MBT.

| Traits		Male (n = 163)				Female (n = 196)				SD_{Index}	Difference (1 − 2)	
		Mean	SD	min-max	As	Mean	SD	min-max	As		t	p
Age [years]		20.41	0.67	19-22	0.78	20.40	0.65	19-22	1.06	0.015	0.099	ns
Body mass [kg]		77.59	11.52	57-124	1.43	60.81	8.09	45-95	0.84	1.711	16.158	<0.001
Body height [cm]		179.73	6.51	162-197	0.27	166.58	5.73	152-185	0.05	2.149	20.344	<0.001
BMI [kg/m²]		23.97	2.80	18.2-35.5	1.32	21.90	2.59	16.5-33.2	0.95	0.768	7.255	<0.001
MET [min/week]		1148.0	226.0	601-1499	−0.66	998.4	236.1	601-1498	0.11	0.647	6.093	<0.001
3-MBT [cycles]	1 min	21.95	3.71	10-33	0.07	19.86	3.07	8-29	−0.17	0.617	5.854	<0.001
	2 min	17.93	4.00	3-28	−0.16	14.80	3.66	3-28	0.29	0.817	7.751	<0.001
	3 min	15.14	4.51	2-25	−0.04	12.13	3.65	0-23	0.23	0.738	6.975	<0.001
	Total	55.02	10.97	15-83	−0.14	46.72	9.39	13-78	−0.02	0.815	7.724	<0.001

Table 2. Arithmetic means in men (n = 163)(n= 196) and women during the 3-MBT depending on the duration of exercise.

| Sex | Duration of 3-MBT [cycles] | | | | | | Difference | | HSD (post-hoc) | | |
| | 1st minute | | 2nd minute | | 3rd minute | | | | | | |
	Mean	SD	Mean	SD	Mean	SD	F	p	1st-2nd	1st-3rd	2nd-3rd
Men	21.95	3.71	17.93	4.00	15.14	4.51	114.59	<0.001	<0.001	<0.001	<0.001
Women	19.86	3.07	14.80	3.66	12.13	3.65	250.88	<0.001	<0.001	<0.001	<0.001

DISCUSSION

The results of this study support the hypothesis that the values of anthropometric characteristics and motor performance are generally higher in men than in women [21]. The endurance-strength abilities measured in the 3-MBT were also higher (*SD* = 0.8) in males than in females. Similar observations were made in a previous study, where motor performance was 23.7% higher in male than female participants during the 3-MBT [22]. These findings could explain why men were able to produce and maintain higher power over a longer period of time in the present study. This observation is validated by the results reported by Garhammer [23] who examined the power output of elite weightlifters during competitions and found that male performers were characterized by higher power in both absolute and relative terms. Similar differences were reported in the load that maximizes power output between men and women [24, 25].

Thomas et al. [26] reported the main effect of sex on the optimal load in squat jump and bench press throw exercises in collegiate soccer athletes. Based on the above findings, Garhammer [23] concluded that women have a lower capacity in slower, strength-oriented lower body activities than in faster, power-oriented lower body activities. The parts of the body that are more engaged during the 3-MBT and the corresponding differences between male and female participants were not investigated during previous studies on the 3-MBT. The 3-MBT is a whole body exercise that engages all muscle groups [8, 10-12]. Whole-body movements, such as the Burpee, in sport-specific training may improve strength, deliver conditioning gains and significantly increase the participants' skills and abilities. These integrated multidimensional activities are more compatible with performance goals and they make better use of time [8].
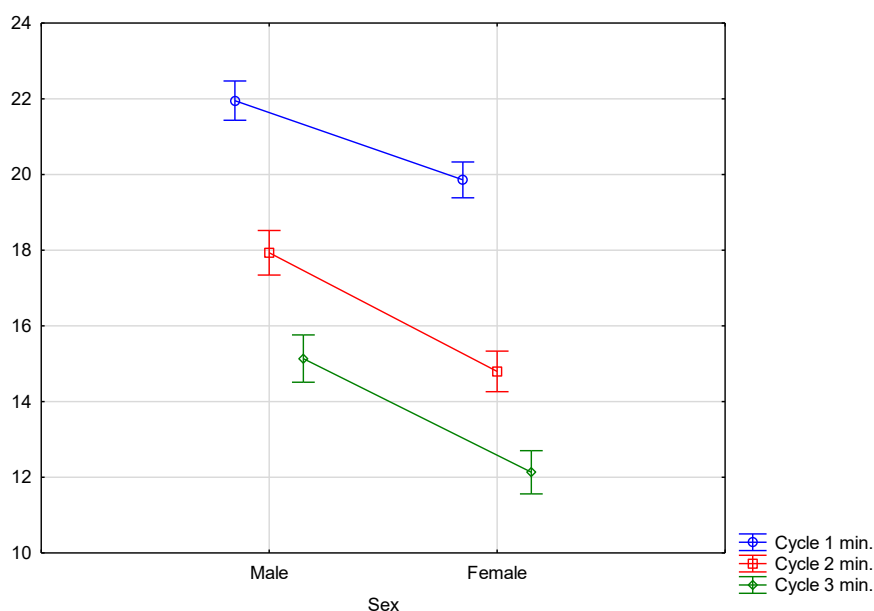
Figure 1. Number of cycles completed by male (n = 163) and female (n = 196) participants in successive minutes of the 3-MBT.

Sex differences become apparent during puberty, adolescence and in early adulthood [27]. The movement kinematics of preschoolers to middle school students are used to examine developmental aspects and sex differences in fundamental movement patterns [28]. Previous research into somatic and motor development across age groups demonstrated that boys have a significant and increasing advantage over girls in throwing performance already in elementary school [29]. These findings can be partially attributed to environmental factors [30]. Despite scientific evidence that PA levels decrease significantly between adolescence and adulthood [31, 32], in particular in the first year of university [33], in global terms, PA levels are generally higher in men then in women, with the exception of several Eastern European countries [34]. The results of this study confirm the above trend, and they shed new light on the relationship between PA and endurance-strength abilities. In this study, both groups were characterized by moderate PA levels, but men were significantly (p<0.001) more physically active than women.

CONCLUSIONS

Men are characterized by higher values of anthropometric characteristics than women.

The observed differences are most pronounced in height and body mass, and sexual dimorphism is least manifested by BMI scores. Male students also score significantly higher in endurance-strength abilities than women. The values of the sexual dimorphism indicator were highest in the second minute, moderate in the third minute, and lowest in the first minute of the 3-MBT. The decrease in power in successive minutes of the test was higher in women than in men. These observations suggest the PA levels of female and male participants should be examined in greater detail before evaluations of sexual dimorphism in power generation and power decline during the 3-MBT.

HIGHLIGHTS

The study confirmed sexual dimorphism in anthropometric characteristics and endurance-strength abilities. Young men are characterized by significantly higher values of basic anthropometric characteristics (body mass, body height and BMI) and significantly higher power during extreme effort (3-MBT) than their female peers. During extreme effort, the loss of power proceeds less rapidly in men than in women.

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