

# The real determinants of power generation and maintenance during extreme strength endurance efforts: the 3-Minute Burpee Test

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## Abstract

**Introduction.** Anthropometric characteristics and physical activity (PA) levels are often considered as potential variables that can be significantly correlated with specific motor abilities. **Aim of Study.** The aim of this study was to evaluate the relationships between anthropometric characteristics and motor abilities with the use of a methodological approach that is rarely applied in physical culture sciences. The correlations between body mass, body height, BMI and PA levels vs sequential power decrease in successive minutes of the 3-Minute Burpee Test (3-MBT) were analyzed. **Material and Methods.** The study involved 359 full-time university students aged 19-22, including 163 male ( $20.4 \pm 0.67$  years) and 196 female ( $20.4 \pm 0.65$  years) participants. Anthropometric characteristics (body mass, height and BMI), PA level (MET units) were measured according to standardized guidelines before the test. The participants' strength endurance were evaluated with the use of the 3-MBT. The results were processed statistically by calculating third-order partial correlation coefficients. **Results.** Raw score correlation coefficients were statistically significant ( $p$ -values: 0.05-0.01), excluding body height which was not bound by significant correlations with the number of cycles completed by women in each minute of the 3-MBT and the number of cycles completed by men in the first minute of the 3-MBT. However, the third-order partial correlation analysis demonstrated that PA level was the only independent variable that was significantly correlated with the results scored in the entire 3-MBT and in successive minutes of the test. In both sexes, the lowest values were observed in the first minute, and they were considerably higher in the second minute of the test. **Conclusions.** In the group of the analyzed variables, only PA levels significantly influence the strength endurance of moderately physically active young women and men during the 3-MBT.

**KEYWORDS:** strength endurance, extreme efforts, university students, 3-Minute Burpee Test.

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## Introduction

Previous research into the 3-Minute Burpee Test (3-MBT) demonstrated that the participants' somatotype significantly influences their performance, and that exercise effectiveness measured by the number of completed burpees (cycles) generally decreases during the 3-MBT with an increase in the values of anthropometric characteristics. Exercise performance is bound by the strongest negative correlations with body mass, followed by BMI, whereas no correlations or weak correlations were noted with body height [17, 19]. Research by Alberghini [3] conducted separate comparisons of anthropometric values in subjects performing a 100-yard dash, a broad jump the burpee test, and identified a series of common correlations in all three trials. However, the anthropometric values associated with

age, height and weight were most highly correlated with burpee performance [3].

Despite the growing popularity of burpees as an effective exercise in sports and functional training [4, 20], the relevant research is rather limited. The applicability of the burpee test has been recognized mainly in martial arts [9, 23] and high-intensity interval training [14]. However, very few researchers have investigated the sequential power decrease in successive minutes of the 3-MBT and its relationship with anthropometric characteristics. The correlations between the participants' performance during the 3-MBT and their physical activity (PA) levels have also been rarely studied [21]. Physical activity levels can be bound by significant and varied correlations with the number of cycles completed in successive minutes of whole-body aerobic resistance exercises such as the 3-MBT [4]. This study contributes new observations regarding a wider application of the 3-MBT as a relevant and reliable tool for measuring strength endurance in adults, in both individual and population assessments. A sequential analysis was performed to determine the relationships between the anthropometric characteristics of young men and women and the decrease in power in successive minutes of the 3-MBT.

### **Aim of Study**

The aim of this study was to evaluate the relationships between the anthropometric characteristics (body mass, body height and BMI) and the PA levels of male and female university students and the number of cycles completed in successive minutes of the 3-MBT as an indirect indicator of the generated power.

### **Material and Methods**

#### *Participants*

The study involved 359 full-time university students aged 19-22, including 163 men (mean age of  $20.4 \pm 0.67$  years) and 196 women (mean age of  $20.4 \pm 0.65$  years). To increase the reliability of the results, the 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). During preparatory meetings held before the study, every participant performed the 3-MBT five times to ensure the reliability of measurements [18].

#### *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 International Physical Activity Questionnaire (IPAQ, Polish short version) was used to evaluate the participants' PA levels before the study using [12]. In the questionnaire, the students indicated the duration of exercise (minimum of 10 minute bouts) performed in the weeks preceding the study. The associated energy expenditure was calculated and expressed in Metabolic Equivalent of Task (MET) units based on the Compendium of Physical Activities coding scheme [1]. The students were divided into groups with low ( $L < 600$  METs-min/week), moderate ( $M < 1500$  METs-min/week) and high ( $H \geq 1500$  METs-min/week) PA levels. Only students with moderate PA levels were included 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 on a calibrated WB-150 medical scale with a stadiometer (ZPU Tryb Wag, Poland) according to standardized guidelines. The measured values were used to calculate the participants' BMI scores.

Strength endurance levels were evaluated based on the number of burpee cycles completed in 3 minutes [20].

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. After the trial, the values recorded in each minute of the test were summed up.

Comments: The exercise has to be performed correctly, and the entire cycle has to be completed in the indicated order. The participants have to maintain the plank position on extended arms without arching the back, but an exception can be made for individuals with low 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*

The results were processed statistically by calculating third-order partial correlation coefficients. A partial correlation is a correlation between a pair of variables that accounts for their relationship with another (third) variable (first-order partial correlation) or several (*n*) other variables (*n*-order partial correlation). This approach is applied to determine the whether variables A and B are still correlated when the relationships between the remaining variables are eliminated (which is equivalent to the assumption that the remaining variables have constant values).

**Results**

The raw score correlation coefficients between the number of completed cycles in successive minutes of the 3-MBT vs the analyzed anthropometric features (body mass, body height, BMI) and METs, calculated

**Table 2.** Raw score correlation coefficients between the studied anthropometric features and METs in males and females

	Male	BM	BH	BMI	MET
Female					
BM			<b>0.589</b>	<b>0.868</b>	<b>-0.398</b>
BH		<b>0.468</b>		ns	ns
BMI		<b>0.847</b>	ns		<b>-0.415</b>
MET		<b>-0.491</b>	ns	<b>-0.485</b>	

Note: BM – body mass, BH – body height, BMI – body mass index, MET – number of METs indicating PA level. Regular font denotes p-values: 0.05-0.01; bold <0.001; ns – not significant

If all of the analyzed variables are significantly correlated, the question that remains to be answered is which anthropometric features or METs actually influence the results of the 3-MBT. This problem can be solved by calculating third-order partial correlation coefficients between the studied anthropometric features and the number of completed burpees. Physical activity level

**Table 1.** Raw score correlation coefficients between the studied anthropometric features and the number of cycles in successive minutes of the 3-MBT

Time	Male (N = 163)					Female (N = 196)				
	NC	BM	BH	BMI	MET	NC	BM	BH	BMI	MET
1 min	21.95	<b>-0.344</b>	ns	<b>-0.387</b>	<b>0.707</b>	19.86	<b>-0.398</b>	ns	<b>-0.443</b>	<b>0.659</b>
2 min	17.93	<b>-0.451</b>	-0.180	<b>-0.455</b>	<b>0.827</b>	14.80	<b>-0.526</b>	ns	<b>-0.533</b>	<b>0.806</b>
3 min	15.14	<b>-0.454</b>	-0.175	<b>-0.461</b>	<b>0.816</b>	12.13	<b>-0.496</b>	ns	<b>-0.502</b>	<b>0.793</b>
Total	55.02	<b>-0.468</b>	-0.160	<b>-0.486</b>	<b>0.876</b>	46.72	<b>-0.551</b>	ns	<b>-0.569</b>	<b>0.849</b>

Note: NC – number of cycles, BM – body mass, BH – body height, BMI – body mass index, MET – number of METs indicating PA level. Regular font denotes p-values: 0.05-0.01; bold <0.001; ns – not significant

separately for men and women, are presented in Table 1. The evaluated correlations were statistically significant, excluding body height which was not bound by significant correlations with the number of cycles completed by women in each minute of the 3-MBT and the number of cycles completed by men in the first minute of the 3-MBT.

The noted values of correlation coefficients in the studied population could be influenced by the presence of strong correlations between the number of burpees completed in each minutes of the 3-MBT and the anthropometric features in both sexes, excluding body height which was not significantly correlated with BMI or MET (Table 2).

**Table 3.** Third-order partial correlation coefficients between the studied anthropometric features and the number of cycles in successive minutes of the 3-MBT

Time	Male (N = 163)				Female (N = 196)			
	BM	BH	BMI	MET	BM	BH	BMI	MET
1 min	ns	ns	ns	<b>0.649</b>	ns	ns	ns	<b>0.565</b>
2 min	ns	ns	ns	<b>0.782</b>	ns	ns	ns	<b>0.733</b>
3 min	ns	ns	ns	<b>0.768</b>	ns	ns	ns	<b>0.718</b>
Total	ns	ns	ns	<b>0.845</b>	ns	ns	ns	<b>0.791</b>

Note: BM – body mass, BH – body height, BMI – body mass index, MET – number of METs indicating PA level. Regular font denotes p-values: 0.05-0.01; bold <0.001; ns – not significant

(expressed by METs) was the only independent variable that was significantly correlated with the results scored in both the entire 3-MBT and in successive minutes of the test (Table 3). In both sexes, the lowest values were observed in the first minute, and the values noted in the second minute were considerably higher (Table 3).

### Discussion

This study relies on an original approach to interpreting the relationships between the results of the 3-MBT and variables such as the participants' anthropometric characteristics and PA levels. The main limitation of many studies investigating the correlations between anthropometric features and motor abilities is that all variables are linked, and the final result of a motor ability test is a product of numerous factors.

The investigated variables are strongly correlated, which prevents a reliable assessment of whether motor abilities are directly influenced by body height, body mass, BMI or the participants' PA levels. The relationships between anthropometric characteristics, PA levels and motor abilities are often difficult to determine in preschoolers and early elementary school students where the analyzed correlations are highly varied and not as obvious as in older subjects [15]. It should also be noted that the motor test applied in this study (3-MBT) is a hybrid exercise that evaluates both endurance and strength abilities. According to some authors, selected groups of motor abilities have a more complex character, where a single dominant ability cannot be identified [25]. Motor abilities and bodily movements have a highly complex structure; therefore, many tests do not measure specific motor abilities, but their combinations. Save for a few exceptions, most motor tests evaluate physical fitness levels rather than potential motor performance (aptitude and motor abilities) [24]. Therefore, exercises that promote strength and endurance are often referred to as strength endurance tests [10]. Regardless of the semantic content, the hybrid nature of motor tests complicates the interpretation of the results. The results of the published studies indicate that high body mass and high body fat percentage exert a negative effect on endurance [7, 27], whereas high body mass and body height are essential in strength sports [13, 16]. These correlations appear to be more varied in sports disciplines that rely on strength endurance. Low body fat percentage and large body size are an advantage in martial arts such as judo [11]. Professional gymnasts are characterized by low body height, very low body mass and relatively high lean body mass [26]. Relative strength plays an important role in strength endurance training, and this parameter

is significantly influenced by body mass [2, 8]. In the current study, male and female students with lower body mass had to overcome lower resistance during the 3-MBT [17].

Most studies investigating the relationships between anthropometric characteristics and motor fitness (MF) involve competitive athletes in specific sports disciplines. These subjects participate in strenuous training programs, most of which are developed for teams and groups, in preparation for competitive events, and they are characterized by high and very similar PA levels. Even in individual training programs, the number of exercise hours is high enough to guarantee very high PA levels. In contrast, the university students evaluated in this study were characterized by moderate PA levels ranging from 600 to 1500 METs/week. The results scored by individuals whose PA levels were closer to the lower limit of the moderate activity category could deviate significantly from the results scored by participants whose PA levels were closer to the upper limit. Therefore, PA levels significantly influenced the results of the 3-MBT despite the fact that the analyzed anthropometric characteristics were also bound by significant straight-line relationships with the number of completed burpees. An in-depth statistical analysis revealed that unlike PA levels, anthropometric characteristics were not bound by significant correlations with strength endurance. The reasons for the above can be found in an analysis of the mutual interactions between PA levels and MF. A systematic review of the literature conducted by Wartburton et al. [28] revealed a clear dose-response relationship between PA and selected health indicators, including MF. However, PA and MF exert independent effects on health indicators [5, 29]. The existing research suggests that improvements in physical fitness (PF) are most conducive to minimizing selected health risks [22] and that PF exerts a greater influence on health indicators than PA [6]. The above findings suggest that low levels of PF are a risk factor that is directly associated with a sedentary lifestyle [29]. In the present study, the results of the in-depth statistical analysis indicate that the PA levels of male and female university students were the only factor that influenced the generation of power and its decline in successive minutes of the 3-MBT. This observation could suggest that the range of MET values for assessing PA levels in the IPAQ (600-1500 MET) is too broad.

### Conclusions

In the group of the analyzed variables, including body mass, body height, BMI and PA level (METs), only the

last factor exerted a significant influence on the strength endurance of moderately physically active male and female university students performing the 3-MBT.

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