Correlations between anthropometric indicators, heart rate and endurance-strength abilities during high-intensity exercise of young women

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Abstract

Background & Study Aim: The optimum level of the endurance-strength abilities is necessary to perform professional activities, and many other daily tasks. The objective of this study was the correlations between anthropometric indicators, BMI, heart rate and endurance-strength abilities of young sedentary women.

Material & Methods: Seventy-two female students of the University of Warmia and Mazury in Olsztyn (Poland) with the mean age 20.6 ±0.66 years were tested. The participants' body mass, body height, length of upper and lower limbs, and BMI were determined. Their endurance-strength abilities were measured in the 3-minute Burpee Test (3MBT). The students' heart rate (HR) was measured immediately before and after the test, and 30-, 60- and 90 seconds after the test. The results were processed statistically and correlation coefficients r were calculated to determine the relationships between anthropometric indicators, HR and the number of completed 3MBT cycles.

Results: The average 3MBT result was 48.58 cycles/3 minutes, the participants' HR increased to 181.92 $b*min^{-1}$, with average increment of 71.88 $b*min^{-1}$. Heart rate values in successive measurements ($T_2 – T_5$) were significantly ($p<0.05$) higher than resting HR (T_1). Heart rate values decreased significantly ($p<0.05$) every 30 seconds after the test (between T_2:T_3, T_3:T_4 and T_4:T_5) to reach 150.96 $b*min^{-1}$ on average after 90 seconds. The number of completed 3MBT cycles was significantly negatively correlated with the participants' body mass, height and BMI.

Conclusions: An increase in anthropometric indicators, including body mass and height, and BMI contributes to a significant decrease in endurance-strength abilities of young women performing the 3MBT. The significant increase in HR and high HR values immediately after exercise indicate that the test involves very high levels of physical exertion.

Keywords: Burpee test • BMI • HR • exertion • physical exercise

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3MBT – 3-minute Burpee test [28]

%-VO2 max – percentage of maximum oxygen consumption

HR – heart rate

MHR – maximum heart rate

%-MHR – percentage of maximum heart rate

IPAQ – International Physical Activity Questionnaire [26]

RPE – Rating of Perceived Exertion [29]

Introduction

The presence of relationships between anthropometric features and endurance-strength abilities has been demonstrated in many studies. Most research focuses on athletes participating in sports such as rowing [1], canoeing [2], wresting [3], judo [4] and gymnastics [5]. The results of studies investigating athletes who are involved in strength and endurance sports indicate that anthropometric indicators significantly influence the contestants' motor fitness levels and, consequently, their performance during sports events.

Most female and male elite rowers and canoeists are taller and heavier than other endurance athletes [6]. Rowers with high-level sports performance are generally characterized by higher values of anthropometric indicators and leaner body mass than the average person [1, 7]. According to Sheldon, female judo and wresting athletes can be classified into more diverse somatic types. The somatic typology of female judo and wresting contestants is more varied in younger age groups, whereas most judo champions are mesomorphs as well as endomorphs with lower body fat percentage and higher lean body mass are also encountered [4]. Female judo and wrestling athletes with high lean body mass are characterized by relatively high isometric strength and high endurance-strength abilities [8]. High body mass and high BMI significantly decrease relative strength and coordination abilities in gymnasts [9].

There has been far less research into the relationships between anthropometric indicators and endurance-strength abilities of sedentary women [10] who are also referred to as not physically active [11]. The results of studies targeting sedentary respondents revealed that anthropometric indicators significantly influence motor abilities. High body mass and high BMI significantly reduce cardiorespiratory fitness, endurance [12, 13] and relative strength [14], but they are positively correlated with absolute strength [15]. The relationships between anthropometric indicators and endurance-strength abilities of sedentary women performing high-intensity exercise have not been widely researched.

Exercise intensity can be measured with the involvement of several methods. In one of the most popular methods, oxygen consumption is measured during physical activity and it is expressed as the percentage of maximum oxygen consumption, %VO2 max. This method is most frequently used in a research setting. In a different approach, the increase in HR associated with exercise is measured. The HR increases with an increase in the intensity of the performed activity. The results are expressed as the percentage of maximum HR, %MHR [16]. Heart rate measurements are most often performed to determine the intensity of daily life activities or to set the level of exercise in physical training.

The following formula is used to determine the maximum HR: 220 – age in years = MHR. The HR is monitored during exercise, and %MHR is calculated to evaluate exercise intensity [17]. The Rating of Perceived Exertion (RPE) is a simpler method for monitoring the HR, and it corresponds to the measured MHR values [18]. The RPE is determined by asking a person to choose a rating number to describe how difficult an exercise feels (psychological perception). Surveys in which participants rate their perceptions, attitudes and feelings on a scale are known as Likert scale questionnaires. Their perceptions relating to physical exercise are generally consistent with HR measurements, and subjective feelings of exertion provide valuable inputs for learning to exercise at a desired level of intensity. It should be noted, however, that individuals with a sedentary lifestyle tend to overestimate the perceived level of intensity, in particular when performing moderate activity [19].

Endurance-strength abilities are the fundamental element of health-related fitness. The 3-minute Burpee test (3MBT) is one of the tests used in evaluations of endurance-strength abilities, in particular in population studies. According to the Oxford Dictionary, the term "Burpee Test" originated in the 1930s, and it takes its name after the American psychologist Roual H. Burpee [20]. The test was originally designed to measure agility and coordination, and consists of a series of so-called "burpies" – physical exercises consisting of a squat thrust from and ending in a standing position. It should be noted that the Burpee test is highly popular in various sporting communities, and different versions of the test exist. They differ in their spatiotemporal structure, therefore, every variation of the Burpee test can be regarded as an individual test for assessing different motor abilities. The following variations of the Burpee test have been discussed in the literature:

- 10-second Burpee Test – the original Burpee Test which is used in the McCloy Physical Fitness Test [21],
- 20-second Burpee Test – used in the "Fitness for health" test [22],
- 30-second Burpee Test – used by Denisiuk [23] in the Motor Fitness Test for girls, and by Sakamaki [24].

- 60-second Burpee Test – used by Denisiuk [23] in the Motor Fitness Test for boys,
- 3-minute Burpee Test – used to evaluate elementary school students, university students and early education teachers [25].

The objective of this study was the correlations between anthropometric features (body mass, body height, length of lower and upper limbs), BMI, HR and endurance-strength abilities of female university students performing the 3MBT.

Material and methods

Participants

The study was performed on 72 first-year full-time female students of the University of Warmia and Mazury in Olsztyn (Poland) aged 19-21 years (mean age 20.6 ±0.66). The students attended obligatory physical education classes of 90 minutes per week. Since differences in the physical activity levels of students participating in extracurricular activities or sports could significantly distort the examined relationships, students performing additional sports activities as well as those released from physical activity for medical reasons were excluded from the study. All participants resided permanently in the Region of Warmia and Mazury, Poland.

Procedures

The study was performed in observance of the provisions of the Declaration of Helsinki and upon the prior consent of the Bioethics Committee of the University of Warmia and Mazury in Olsztyn. All students gave their written consent to participate in the study.

Measurements

Female students' physical activity levels were evaluated with the use of the Polish version of the standardized and validated International Physical Activity Questionnaire (IPAQ) [26]. The energy expenditure of participants did not exceed 600 METs per week, and none of the tested female students met the "sufficient physical activity" category. IPAQ was used only to select a homogenous sample of female students, and its results are not presented in this study.

Anthropometric indicators (body mass, body height, length of lower limbs – LL, length of upper limbs – UL) were measured according to the methods proposed by Martin. Body height was measured to the nearest 1 mm, and body mass – to the nearest 0.1 kg, with the use of the WB-150 electronic medical weighing scales with a stadiometer (ZPU Tryb-Wag, Poland). The Body Mass Index (BMI = body mass [kg] / body height [m]^2), which is generally regarded as a relevant and reliable statistic for evaluating excessive weight and obesity, was determined to assess the participants' nutritional status (body fat) [27]. Heart rate (HR) was measured with the Polar RS 100 pulse rate meter with a chest strap transmitter. The students' endurance-strength abilities were determined in the 3-minute Burpee test (3MBT) [28]. Perceived exertion was rated on a 5-point scale developed by the American College of Sports Medicine [29] (Table 1).

Table 1. Classification of exercise intensity by the American College of Sports Medicine (ACSM)

Cardiorespiratory Endurance Exercise (RI)		
Intensity	**Maximum Heart Rate (HR Max%)**	**Rating of Perceived Exertion (points in a 6-20 RPE scale)**
Very light	<57%	<9
Light	57-63%	9-11
Moderate	64-76%	12-13
Vigorous	77-95%	14-17
Near-maximal to maximal	96%	≥ 18

Source***:*** Table adapted from the American College of Sports Medicine [29].

The participants' perceptions relating to physical effort are generally consistent with HR measurements, and subjective feelings of exertion provide valuable inputs for learning to exercise at a desired level of intensity. It should be noted, however, that individuals with a sedentary lifestyle tend to overestimate the perceived level of intensity, in particular when performing moderate activity [19]. For this reason, the Likert [30] scale measuring perceptions and attitudes was additionally used to compare the participants' HR values (Table 2).

All measurements (anthropometric, HR and 3MBT) were performed at the UWM gym in April 2015. The participants performed the test once, and the results were assigned the corresponding HR values (immediately before and after the test, after a resting period of 30-, 60- and 90 seconds in a sitting or lying posture on a mat). The results were read out by the tested student and recorded. Every student was shown how to perform the 3MBT during a PE class before the test, and was given ample time to practice it. The participants performed

Table 2. Likert scale measuring perceptions of physical effort

Level of intensity	RPE	Physical cues	RPE
Light	Easy	Does not induce sweating unless performed on a hot, humid day. There is no noticeable change in breathing patterns.	1-2
Moderate	Somewhat hard	Will break a sweat after performing the activity for about 10 minutes. Breathing becomes deeper and more frequent. You can carry on a conversation, but not sing.	3-4
High	Hard	Will break a sweat after 3-5 minutes. Breathing is deep and rapid. You can only talk in short phrases.	5-6

Source: The Weight Watchers Research Department [30].
Notes: **RPE** the Rating of Perceived Exertion

an active warm up for 10 minutes before the tests. The warm up was the same for all students, and it included movement exercises such as a warm up game, trotting, arm, hip and leg swings, balance exercises, short (10 m) runs, stretching and posture exercises [31].

Phases of the 3MBT

Phase I: beginning from an upright standing posture, the participant assumes a supported squatting position with both hands on the ground.

Phase II: from a supported squat, the feet are thrust backwards into the push-up position with straightened arms.

Phase III: the participant once returns to a supported squat.

Phase IV: the cycle is completed when the participant returns to the upright standing posture and simultaneously claps his or her hands over the head, making sure that the arms remain extended. The cycle is performed as many times as possible in the given time limit (3 minutes).

Comments

Attention should be paid to proper form, and every position has to be performed in the given order. When assuming the push-up position, the participants should not bend their arms or arch their backs, but an exception can be made for those who do not have sufficient upper body strength. The legs must be fully extended in the push-up position. A cycle in which any individual step is not performed correctly is not counted [28].

Statistical analysis

The results were processed statistically to calculate minimum, mean and maximum values, median values, standard deviation, coefficient of variation for independent variables (body height, body mass, BMI, length of upper and lower limbs) and dependent variables (HR values immediately before and after the test, and 30-, 60- and 90 seconds after the test, increase in HR). Statistical significance was determined based on the values of correlation coefficients describing the relationships between independent and dependent variables. Calculations were performed by the Statistica v.12, at a significance level of $\alpha = 0.05$.

Results

All of the 72 female participants classified the 3MBT as an exercise with near-maximal to maximal of level intensity with an average of 19.86 ±0.421 points (min-max: 18-20), and they graded it is as a hard exercise with 5.91 ±0.278 points on the Likert scale (min-max: 5-6). The symptoms of exertion observed in students corresponded to those described in the Likert scale (Table 2): the vast majority of participants wanted to rest after the exercise and remained recumbent or sitting on mats for around 6 minutes. During rest, the students were able to speak in short phrases (e.g. when reading their pulse) due to shortness of breath, and they began to sweat profusely after 3-5 minutes.

The results presented in Table 3 indicate that the average BMI of the evaluated female students was within the norm. A significant increase ($p = 0.000$) in HR was noted from the resting HR of 110.13 $b*min^{-1}$ to 182.00 $b*min^{-1}$ during the 3MBT, and maximum HR reached 204 $b*min^{-1}$. The average increase in HR during the 3-minute test was 71.87 $b*min^{-1}$. During successive measurements (from T_2 to T_5), HR values were significantly ($p = 0.000$) higher than resting HR – T_1. During the rest period, HR decreased significantly ($p= 0.000$) every 30 seconds, between T_2:T_3, T_3:T_4, T_4:T_5, to reach the average value of 150.96 $b*min^{-1}$ after 90 seconds (Table 3).

Table 3. Statistical characteristics of the evaluated female students (n = 72)

Variable	Descriptive statistics					
	$\bar{x}$	Median	Minimum	Maximum	SD	r%
Body height [cm]	165.04	165.00	154.00	180.00	5.97	3.62
Body mass (kg]	60.94	59.00	41.00	95.00	10.52	17.26
BMI [kg*m^{-2}]	22.40	21.74	16.41	32.11	3.82	17.07
UL length [cm]	69.50	69.00	64.00	80.00	3.76	5.41
LL length [cm]	77.65	77.50	71.00	91.00	4.33	5.57
No. of cycles [N]	48.58	48.50	42.60	55.80	3.15	6.48
T_1 – HR before test [b*min^{-1}]	110.13	114.00	78.00	144.00	16.94	15.38
T_2 – HR immediately after test [b*min^{-1}]	181.92	183.50	145.00	204.00	12.70	6.98
Increase in HR [b*min^{-1}]	71.88	70.00	37.00	108.00	15.92	22.15
T_3 – HR 30 s after test [b*min^{-1}]	171.32	172.00	140.00	195.00	12.11	7.07
T_4 – HR 60 s after test [b*min^{-1}]	161.92	163.00	132.00	186.00	12.35	7.63
T_5 – HR 90 s after test [b*min^{-1}]	150.96	151.50	112.00	176.00	13.10	8.68
Average HR before and after test	**Pair**	**t**	**p**	**Pair**	**t**	**p**
	T_1:T_2	–38.383	0.000	T_2:T_4	46.200	0.000
	T_1:T_3	–32.681	0.000	T_2:T_5	56.279	0.000
	T_1:T_4	–26.789	0.000	T_3:T_4	26.927	0.000
	T_1:T_5	–20.597	0.000	T_3:T_5	37.732	0.000
	T_2:T_3	38.499	0.000	T_4:T_5	27.651	0.000

Notes: **t** value of the t-test; **p** probability of exceeding the calculated value of t

Significantly negative correlation coefficients *r* were noted for body mass (r = –0.867), BMI (r = –0.779) and body height (r = –0.254). Those results suggest that body mass is the key factor limiting the number of cycles in the 3MBT, followed by BMI and height. None of the measured anthropometric indicators was significantly correlated with an increase in HR or HR values before and after the 3MBT. The only exception was lower limb length which was significantly negatively correlated with HR measured 30 seconds after the test (Table 4).

Discussion

High body fat percentage (BMI) significantly reduces exercise capacity [6]. In a previous study, the above observation was confirmed by 3MBT results scored by young sedentary women with higher BMI [28]. Similar outcomes were noted in sedentary women who rowed for 500 m [11] and 1000 m runs on a rowing ergometer [32]. Body mass was also negatively correlated with performance in a 3-minute endurance test [33].

The results of this study are consistent with the above observations, and they indicate that in addition to BMI, high body mass and high body height also decrease endurance-strength abilities in the 3MBT. This observation can probably be attributed to the frequent change of position in the 3MBT, including squats and lower limb movement in every cycle. The lower limbs are significantly engaged in every phase of the 3MBT, which is not the case in endurance tests performed on a rowing ergometer. This can probably

Table 4. Correlation coefficients r between the analyzed anthropometric parameters and the parameters measured during the 3MBT.

Variable	Indicators measured during the test (n = 72)						
	Cycles	HR before	HR immediately after	HR after 30 s	HR after 60 s	HR after 90 s	HR increase
Body height [cm]	**–0.254**	0.196	–0.001	–0.209	0.002	–0.009	–0.032
Body mass [kg]	**–0.867**	0.063	–0.001	–0.068	0.004	0.054	0.123
BMI [$kg \cdot m^{-2}$]	**–0.779**	–0.017	–0.005	0.013	0.001	0.056	0.136
UL length [cm]	–0.212	0.129	–-0.108	–0.225	–0.091	–0.098	–0.094
LL length [cm]	–0.044	0.215	–0.043	**–0.264**	–0.023	–0.050	–0.089

Notes: values significant at $p \leq 0.05$ are marked in bold

be explained by the fact that rowing is performed in a sitting position (posture), and the rowers' body mass is supported by the boat (rowing ergometer). This, in turn, implies that higher body mass does not detract from the rower's performance [34]. A base of support in a sitting position significantly reduces body mass, and the sitting position is more stable than the position during the 3MBT.

The very high HR values (181.92 b^*min^{-1}) immediately after the 3MBT indicate that the 3-minute exercise led to considerable exertion. In young athletes, HR values range from <40 b^*min^{-1} at rest to >200 b^*min^{-1} under maximum load.

Seiler and Kjerland [35] reported average HR values of 198±9 b^*min^{-1} with min-max range of 189-220 $b \cdot min^{-1}$ in cross-country skiers during interval training performed at maximum and near-maximum intensity. Faff et al. [36] performed an extensive study of HR_{max} values in 1589 male and 1180 female athletes aged 13-32 years training under various conditions. The athletes' performance was monitored during cycling, running on a treadmill, kayaking, rowing and skiing. In the group of female athletes, the highest HR_{max} values were reported during treadmill running 198.7±1.4 b^*min^{-1}, rowing 196.4±6.8 b^*min^{-1}, cycling 192.7±7.6 b^*min^{-1}, kayaking 192.3±7.0 b^*min^{-1}, and skiing 188.2±8.7 b^*min^{-1}. Those results indicate that some activities impose a greater physical load on the body despite similar levels of commitment exhibited by the participants [37].

In this study, the high HR values (relative to the values noted in athletes) in sedentary women performing the 3MBT point to even higher levels of difficulty. The participants' subjective perceptions of effort invested in the 3MBT can be used to determine the level of exertion based on HRMax% values. According to the American College of Sports Medicine (Table 1), a score of ≥18 points corresponds to 96% HRMax%. Those observations were confirmed by the participants in this study who evaluated the 3MBT as a hard exercise characterized by a high level of intensity on the Likert scale. Similar opinions have been voiced by coaches and athletes who use the 3MBT in their training programs [38-40]. It should be noted, however, that maximum HR varies innately among individuals [41], it decreases with age [42], but does not increase with training [43]. Sport-specific hemodynamic conditions may also play an important role in cardiac remodeling [42].

Practical implications

Three-minute bursts of high-intensity physical activity are analyzed in research because many sporting disciplines, in particular martial arts, rely on such time intervals during competitions. Three-minute rounds are found in various weight and age categories of male and female contestants involved in boxing, judo, ju-jitsu, taekwondo and karate. A highly interesting analysis of a 3-minute high-intensity exercise was carried out by Bangsbo et al. [44] who demonstrated that during strenuous activity of the lower limbs that led to exhaustion in 3 minutes, ATP was supplied by anaerobic processes in 45% and by aerobic processes in 55%. Anaerobic processes supplied 80% of ATP in the first 30 seconds of the exercise, but only 30% of ATP in the last minute.

Krutstrup et al. [45] calculated heat production during a 3-minute high-intensity exercise involving the knee extensor muscle at 86 J^*s^{-1} in the first 15 seconds and

157 J*s^{-1} in the last 15 seconds. Total heat production in successive minutes of the activity was 22.8±1.1, 23.8±1.7 and 25.9±2.6 J*s^{-1}. Lactic acid concentration was determined at 3.9±0.6 mmol*min^{-1} after the first minute and 11.8±1.1 mmol*min^{-1} after three minutes of the exercise. It should be noted, however, that the above results were noted in an activity test engaging the quadriceps femoris muscle only. Our findings provide new information about a 3-minute high-intensity hybrid exercise (endurance and strength) that engages the entire body.

Hemodynamic conditions, in particular variations in cardiac output and peripheral vascular resistance, differ significantly across sporting disciplines. Despite certain overlaps, there are two major types of physical exercise with characteristic hemodynamic differences Isotonic exercise, also known as endurance exercise, involves sustained increase in cardiac output, while peripheral vascular resistance remains normal or is reduced [45].

Many sports combine elements of endurance and strength exercises, including popular team-based activities such as American football, rugby, basketball and hockey. After the development of the relevant classification norms, the 3MBT can be used to evaluate motor fitness in athletes engaged in similar sporting disciplines.

Conclusions

High body mass, high body height and high BMI are negatively correlated with the endurance-strength abilities of young sedentary women in the 3MBT. A significant increase in HR values and high average HR during the test indicate that the 3MBT is a very high-intensity exercise which requires significant physical effort.

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Conflict of interest

The authors declare that they have no conflict of interest.

References

1. Battista RA, Pivarnik JM, Dummer GM et al. Compositions of physical characteristics and performances among female collegiate rowers. J Sport Sci 2007; 25(6): 651-657
2. Kerr RM, Spinks W, Leicht AS et al. Predictors of 1000-m outrigger canoeing performance. Int J Sport Med 2008; 29(8): 675-678
3. Oppliger RA, Case HS, Horswill CA et al. ACSM Position Stand: Weight Loss in Wrestlers. Med Sci Sport Exer 1996; 28(10): 135-138
4. Franchini E, Huertas JR, Sterkowicz S et al. Anthropometrical profile of elite Spanish Judoka: Comparative analysis among ages. Arch Budo 2011; 7(4): 239-245
5. Claessens AL, Veer FM, Stijnen V et al. Anthropometric characteristics of outstanding male and female gymnasts. J Sport Sci 1991; 9(1): 53-74
6. Yoshiga CC. Higuchi M. Oxygen uptake and ventilation during rowing and running in females and males. Scan J Med Sci Sport 2003; 13(5): 359-363
7. Bourgois J, Claessens AL, Janssens M et al. Anthropometric characteristics of elite female junior rowers. J Sport Sci 2001; 19(3): 195-202
8. Bonitch-Góngora JG, Almeida F, Padial P et al. Maximal isometric handgrip strength and endurance differences between elite and non-elite young judo athletes. Arch Budo 2012; 9(4): 239-248
9. Sands WA, McNeal JR, Jemni M et al. Should Female Gymansts Lift Weights? Sport Sci 2000; 4(3): 1-6
10. Tasmektepligil MY, Agaoglu SA, Türkmen L et al. The motor performance and some physical characteristics of the sportswomen and sedentary lifestyle women during menstrual cycle. Arch Budo 2010; 6(4): 195-203
11. Podstawski R, Choszcz D, Konopka S et al. Anthropometric determinants of rowing ergometer performance in physically inactive collegiate females. Biol Sport 2014; 31(4): 315-321
12. Crecelius AR, Vanderburgh PM, Laubach LL. Contributions of Body Fat and Effort in the 5K Run: Age and Body Weight Handicap. J Strength Cond Res 2008; 22(5): 1474-1480
13. Vanderburgh PM, Laubach LL. Body Mass Bias in a Competition of Muscle Strength and Aerobic Power. J Strength Cond Res 2008; 22(2): 375-382
14. Caruso JF, Coday MA, Ramsey ChA et al. The impact of resistive exercise training on the relationship between anthropometry and jump-based power indices. Isokinet Exerc Sci 2009; 17: 41-50
15. Mondal A, Majumdar R, Pal S. Anthropometry and Physiological Profile of Indian Shooter. Int JAppl Sport Sci 2011; 23: 394-405
16. Hiilloskorpi HK, Pasanen ME, Fogelholm MG et al. Use of heart rate to predict energy expenditure from low to high activity levels. Int J Sport Med 2003; 24(5): 332-336
17. Plews DJ, Laursen PB, Kilding AE et al. Heart-rate variability and training-intensity distribution in elite rowers. Int J Sport Physiol Perform 2014; 9(6): 1026-1032
18. Dunbar CC, Kalinski MI. Using RPE to regulate exercise intensity during a 20-week training program for postmenopausal women: a pilot study. Percept Motor Skill 2004; 99(2): 688-690
19. Duncan GE, Sydeman SJ, Perri MG et al. Can sedentary adults accurately recall the intensity of their physical activity? Prev Med 2001; 33(1): 18-26
20. Oxford Dictionaries. Available from: URL: http://www.oxforddictionaries.com/definition/english/burpee (accessed 2015 May 24)
21. Mc Cloy CH, Young MD. Tests and measurement in health and physical education. New York: Appleton-Century-Crofts; 1954
22. Pilicz S. Gdzie sprawność – tam zdrowie. Warszawa: Sport i Turystyka; 1984 [in Polish]
23. Denisiuk L, Milicerowa H. Rozwój sprawności motorycznej dzieci i młodzieży w wieku szkolnym. Warszawa: PZWL; 1969 [in Polish]
24. Sakamaki T. A study of the burpee push up test as a simple method of measuring endurance, Nippon Ika Daigaku Zasshi 1983; 50(2): 173-190 [in Japanese]
25. Podstawski R, Honkanen A, Boraczyński T et al. Physical fitness classification standards for Polish early education teachers. S Afr J Res Sport Ph 2015; 37(1): 113-130
26. Biernat E, Stupnicki R, Gajewski AK. International Physical Activity Questionnaire (IPAQ) Polish Version. Phys Educ Sport 2007; 51(1): 47-54
27. Mei Z, Grummer-Strawn LM, Pietrobelli A et al. Validity of body mass index compared with other body-composition screening indexes for the assessment of body fatness in children and adolescents. Am J Clin Nutr 2002; 75: 978-985
28. Podstawski R, Kasietczuk B, Boraczyński T et al. Relationship Between BMI and Endurance-Strength Abilities Assessed by the 3 Minute Burpee Test. Int J Sport Sci 2013; 3(1): 28-35
29. Garber CE, Blissmer B, Deschenes MR et al. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and

neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. Med Sci Sport Exerc 2011; 43(7): 1334-1359
30. Exercise Intensity Levels. How to measure exercise. Intensity. Available from: URL: http://www.weight-watchers.com/util/art/index_art.aspx?tabnum=1&art_id=20971 (accessed 2015 May 24)
31. Frandkin AJ, Zazryn TR, Smoliga JM. Effects of warming-up on physical performance: a systematic review with meta-analysis. J Strength Cond Res 2010; 24(1): 140-148
32. Podstawski R, Choszcz D, Siemianowska E et al. 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 2012; 20: 1-8
33. Ivanović M, Ivanović U. Anthropometric and motor determinants of endurance running in pre-adolescent age. Acta Kinesiol 2011; 5(1): 34-39
34. Steinacker JM. Physiological aspects of training in rowing. Int J Sport Med 1993; 14: 3-10
35. Seiler KS, Kjerland GQ. Quantifying training intensity distribution in elite endurance athletes: is there evidence for an “optimal” distribution? Scand J Med Sci Sport 2006; 16: 49-56
36. Faff J, Sitkowski D, Ładyga M et al. Maximal Heart Rate in Athletes. Biol Sport 2007; 24(2): 129-142
37. Dalleck L, Dalleck A. The ACSM exercise intensity guidelines for cardiorespiratory fitness: why the misuse? J Exerc Physiol 2008; 11(4): 1-11
38. Atlas J. Burpees: The exercise you should never do again. Available from: URL:http://blogs.denverpost.com/fitness/2013/12/02 (accessed 2015 May 24)
39. Enamalt R. Burpee conditioning – no more nonsense! Available from: URL:http://www.bodybuilding.com/author/ross-enamait (accessed 2015 May 24)
40. Simone M. 3-Minute Fit Test: Chins, Pushs and Burpees. Available from: URL: http://www.mensfitness.com/training/build-muscle/3-minute-fit-test-chins-pushs-and-burpees (available 2015 May 24)
41. Rowell LB. Human Circulation: Regulation During Physical stress. New York: Oxford University Press; 1986
42. Baggish AL, Wood MJ. Athlete’s Heart and Cardiovascular Care of the Athlete Scientific and Clinical Update. Circulation 2011; 123: 2723-2735
43. Uusitalo AL, Uusitalo AJ, Rusko HK. Exhaustive endurance training for 6–9 weeks did not induce changes in intrinsic heart rate and cardiac autonomic modulation in female athletes. Int J Sport Med 1998; 19: 532–540
44. Bangsbo J, Gollnick PD, Graham TE et al. Anaerobic energy production and O2 deficit-debt relationship during exhaustive exercise in humans. J Physiol 1990; 422: 539-559
45. Krutstrup P, González-Alonso J, Quistorff B et al. Muscle heat production and anaerobic energy production during repeated intense dynamic exercise in man. J Physiol 2001; 536: 947–956

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