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ANTHROPOMETRIC CHARACTERISTICS AND ANAEROBIC POWER OF LOWER LIMBS AND THEIR RELATIONSHIPS WITH RACE TIME IN FEMALE SPEED CLIMBERS

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Abstract. *Previous research indicates that high results in speed climbing are determined by a high level of explosive strength and muscle power in the lower limbs. However, a literature review shows that no studies have analysed women practicing this climbing discipline. Therefore, the main goal of the study was to assess the level of development of physique and the level of explosive strength and muscle power of the lower limbs of female speed climbers at a representative level. Furthermore, an attempt was made to analyse the relationships between the variables studied and race time in female speed climbers. The study included 5 female players (speed climbers) who were members of the national team in 2016. The measurements were made during the Polish National Team Camp. The analysis was based on the results of the fastest races expressed in seconds. The measurements and indices computed in the study included body height, body weight, lean body mass, BMI and ponderal index. The assessment of the power of the lower limbs was carried out using two jump tests: CMJ with arm swing and CMJ. Power was expressed relative to body weight and to lean body mass. The highest relationships with race time were recorded for body height ($r = 0.94$, $p < 0.05$), body weight ($r = 0.96$, $p < 0.01$) and lean body mass (LBM) ($r = 0.98$, $p < 0.01$). Strong but statistically insignificant relationships were recorded between race time and power indicators of the lower limbs (correlations above $r = -0.66$). In female speed climbing, race time can be determined by the level of physique. Smaller body size can allow female climbers to perform faster and achieve better times in speed climbing. It can be suggested that in female speed climbing, a high level of maximum alactic anaerobic capacity of the lower limbs is an important factor that affects race time. The results of our own research suggest that in female speed climbing, specific body characteristics may to a greater extent determine the race time compared to anaerobic maximum power of the lower limbs.*

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Keywords: *explosive strength, female speed climbing, lower limbs, maximum anaerobic power, sport climbing.*

Introduction

Sport climbing includes three disciplines which differ depending on motor demands: speed climbing, bouldering and lead climbing. In 2016, the International Olympic Committee made a decision on qualification of sports climbing to the programme of the Olympic Games in Tokyo in 2020. The event format that combines the three climbing disciplines (combined format) means that the best athletes from all the disciplines will compete with each other during Tokyo Olympics. Previous research on sports climbing was performed mainly among climbers who compete in lead climbing (Watts et al., 1993; Mermier et al., 2000; Rokowski & Tokarz, 2007; Rokowski & Żak, 2010; Tomaszewski et al., 2011; Ozimek et al., 2017). The examinations were also performed in groups of boulderers (Michailov et al., 2009; White & Olsen, 2010; Macdonald & Callender, 2011; Ozimek et al., 2017) and speed climbers (Ryepko, 2013; Krawczyk & Ozimek, 2014; Krawczyk et al., 2015a; Krawczyk et al., 2015b).

In light of the analysis of scientific literature related to lead climbing, morphofunctional factors which determine sports result have been sufficiently examined, which allowed for identification of this discipline as an endurance and strength sport. The most important factors in bouldering include: relative strength of fingers, rate of force development over time and maximal anaerobic power of the upper limbs. In light of current research, speed climbing, which has been little explored to date, is characterized by high requirements in terms of strength and speed abilities. The principle difference between individual disciplines consists in the different role of the upper and lower limbs. Unlike in two other disciplines, the major role in speed climbing is played by the lower limbs (Krawczyk et al., 2015a).

In terms of somatic build, it was found that the biggest effect in the context of the achievement of a high sports skill level in sport climbing is from average body build, low body mass and low body fat percentage (Watts et al., 1993; Watts, 2004; Sheel, 2004; Giles & Brandenburg, 2017). Some studies have demonstrated that specific body build proportions can be a factor in sport climbing (Rokowski, 2006; Tomaszewski et al., 2011; Ozimek et al., 2017).

In light of the literature analysis, it can be concluded that no research has been conducted to examine groups of women who competed in speed climbing. Previous research in the area of speed climbing was based on the examinations of male athletes which indicate high importance of maximum alactic anaerobic power of the lower limbs. Therefore, and with consideration for the fact that women will participate in the Olympic Games in Tokyo, the main aim of this study was to evaluate the level of the development of the somatic build and level

of anaerobic capacity of the lower limbs of female speed climbers. Furthermore, the attempt was made to determine the correlations of the analysed characteristics and indices with race time for female speed climbers. This knowledge can be used by coaches in physical fitness preparation during the development of training programs for female athletes.

Material and Methods

The examinations were performed in a group of female elite speed climbers (n=5). At the moment of measurements, the climbers were members of the Polish national team who competed in the discipline of speed climbing. Measurements were made during a camp of the national team in February 2016 in the facilities of the State Higher Vocational School in Tarnów. Body height measurements were performed. Body mass (BM), fat percentage (FM %) and lean body mass (LBM) was evaluated by means of the TANITA model BC-730 according to recomendations Lohmann et al. (1997). These measurements were used to compute ponderal index and BMI. Explosive strength of the lower limbs of climbers were measured using the counter-movement jump with arm swing (CMJ) and counter-movement jump without arm swing (CMJb), with each jump performed twice, with the better result recorded in cm. Jump height was used to compute the level of maximal alactic anaerobic power (Pmax CMJ and Pmax CMJb) expressed in absolute values (W) and relative to body mass (W/kg) and to lean body mass (W/kg LBM). The study also used the equation developed by Sayers et al. (1999). The tests were performed by means of the Optojump Next measurement system (Microgate, Bolzano, Italy).

The statistical analysis of the data collected in the study used the following calculations:

1. Basic descriptive statistics were computed (arithmetic mean, standard deviation and coefficient of variation for each variable);
2. The Shapiro-Wilk test was conducted to evaluate the consistency of the distribution of variables with normal distribution;
3. The linear Pearson's correlations was used and correlation coefficients $r_{(xy)}$ were computed in order to evaluate strength and directions of correlations between the best race time obtained by athletes during training and other variables. Correlation coefficients were presented for the male climbers studied. Analysis of correlations was also performed between the best time and level of explosive strength and anaerobic power of lower limbs for all the athletes studied. The results with correlations coefficients with $p<0.05$ were adopted as statistically significant. For each value of $r_{(xy)}$ we calculated the coefficient of determination R^2.

The collected data were developed using the STATISTICA 8 software package (StatSoft®). The graphical representation of the results was prepared using the Microsoft® Excel software from the Office 2007 package.

Results

Table 1 presents mean values of standard deviations and coefficients of variation calculated for all the analysed variables in the climbers studied. Table 2 presents the results of the analyses aimed to determine strength and directions of correlations between the variables examined and climbing race time. The highest and statistically significant correlations were found for body height, body mass and lean body mass. Correlations indicated that higher body mass (body height, body mass and/or lean body mass) are correlated with longer race times. High but statistically insignificant values of the coefficients of correlation with race time were found in this group for the indices of body build such as BMI and ponderal index. Correlations of race time and the level of parameters of the explosive strength and anaerobic relative power of lower limbs were high but statistically insignificant.

Table 1 **Statistical characteristics of somatic variables, strength parameters and anaerobic power in female climbers**

	x	***sd***	***v%***
BH (cm)	163.74	2.72	1.66
BM (kg)	52.74	4.87	9.23
FM %	17.34	2.92	16.83
LBM [kg]	41.34	3.22	7.79
BMI	19.64	1.26	6.42
ponderal index	43.71	0.77	1.76
race time (s)	9.60	1.83	19.08
CMJ (cm)	39.62	4.39	11.07
CMJb (cm)	34.54	3.84	11.11
Pmax CMJ [W]	2739.06	181.57	6.63
Pmax CMJb [W]	2430.70	141.32	5.81
Pmax CMJ [W/kg]	52.23	5.40	10.33
Pmax CMJb [W/kg]	46.34	4.36	9.40
Pmax CMJ [W/kg LBM]	66.55	6.60	9.92
Pmax CMJb [W/kg LBM]	59.03	5.11	8.65

Table 2 **Values of Pearson correlation coefficients and coefficient of determination R2 between the time of the fastest race and the somatic variables and parameters of anaerobic power**

	r (x,y)	***R^2***	***p-value***
BH (cm)	0.94	0.89	*
BM (kg)	0.96	0.93	**
FM %	0.31	0.10	ns
LBM [kg]	0.98	0.96	**
BMI	0.86	0.74	ns
ponderal index	-0.70	0.49	ns
CMJ (cm)	-0.71	0.51	ns
CMJb (cm)	-0.76	0.57	ns
Pmax CMJ [W]	0.12	0.01	ns
Pmax CMJb [W]	0.26	0.07	ns
Pmax CMJ [W/kg]	-0.72	0.52	ns
Pmax CMJb [W/kg]	-0.72	0.52	ns
Pmax CMJ [W/kg LBM]	-0.66	0.43	ns
Pmax CMJb [W/kg LBM]	-0.67	0.45	ns

** - statistically significant correlation at p<0.05*
*** - statistically significant correlation at p<0.01*
ns – no significant correlation

Discussion

In speed climbing competitions, climbers compete based using the time record format. They ascend a standardized climbing route with height and width of 15 and 3 metres, respectively. Wall inclination is 5º, whereas topographical locations of the holds and footholds are the same for each competitor. Analysis of races during the European Championships in 2017 indicates that race times in female competitions were: 7.68 to 13.11 seconds[1]. Duration of the female race leads to the conclusion that this type of exercise is primarily based on the use of anaerobic processes of energy generation. Therefore the high level of anaerobic capacity will be critical to the ability to perform exercise at maximal or very high intensity. It can be also concluded that high phosphagen performance (ATP-PC system) of the energy system will be one of key components of physical performance in speed climbing.

Muscle power is determined by maximal muscle force and speed of muscle shortening (Wilmore & Costill, 1994; Chmura, 2016). Power, i.e. ability to develop a substantial force of muscle contraction over a relatively short time, largely determines speed of movements (Chmura, 2016). In our study, we used a

[1] Source: http://www.ifsc-climbing.org/index.php/world-competition/results#!comp=6411&cat=24 and http://www.ifsc-climbing.org/index.php/world-competition/results#!comp=6411&cat=23

single maximal jump test to measure power. Time of loading in this test was equal to one movement cycle. Gabryś et al. (2004 as cited in Miszczenko 1990) argued that the level of muscle contraction force during a maximal jump is 100 %, whereas the basic factors that limit the loading power include the amount and composition of muscular tissues. The results of statistical analyses indicated (although statistically significant correlations were not found) that high level of alactic anaerobic maximal power and explosive power of the lower limbs can be important factors that impact on race time in women (high values of $r_{x,y}$ and R^2). The results are consistent with the results of previous studies (Ryepko, 2013; Krawczyk & Ozimek, 2014; Krawczyk et al., 2015a; Krawczyk et al., 2015b), which indicated a high level of explosive strength (anaerobic power) of the lower limbs as a significant determinant of performance in this sport. This leads to the conclusion that the development of alactic maximal anaerobic power should represent one of the major goals in training programs dedicated to this climbing discipline. Furthermore, it can be presumed that in the process of recruitment of athletes for this climbing discipline, determination of the level of alactic maximal anaerobic power of candidates should become an inherent component of the process.

In sport climbing, insignificant body dimensions and low level of adipose tissue are conducive to the achievement of high performance in the sport (Watts et al., 1993; Mermier et al., 2000; Sheel, 2004; Giles & Brandenburg, 2017; Michailov et al., 2009). Rokowski et al. (2016) and Ozimek et al. (2016) conducted an analysis of somatic build of both female and male athletes of all climbing disciplines at an elite level. These studies have shown that in the group of women, female speed climbers differed from lead climbers but were similar in their body build to female boulderers. Comparison of our findings concerning body height and body mass in female climbers with the results documented by Ozimek et al. (2016) indicates that female climbers were characterized by similar mean values (body height: 163.74 vs. 167; body mass: 52.74 vs. 55.8; BMI: 19.64 vs. 19.84; ponderal index: 43.71 vs. 43.89). An analysis of the results for means and measures of variability (standard deviation, coefficient of variability) obtained in our research and studies by Rokowski et al. (2016) and Ozimek et al. (2016) indicates that their values were similar. The above reports documented somatic data of athletes classified at top places in the IFSC ranking, which leads to the conclusion that in terms of body build (analysed in these terms), the level of development of somatic characteristics of female climbers from the Poland national team can be treated as a model and that it meets the standards of international-level speed climbers. However, these findings should be approached carefully since our own study and the study by Rokowski et al. (2016) and Ozimek et al. (2016) were performed using the relatively insignificant research samples. This indicates the need for the measurements in bigger groups of athletes.

A high level of development of muscle mass (including skeletal muscle mass, especially with high content of type 2 fibres) has a substantial effect on strength and anaerobic power (Bompa & Haff, 2010) and can significantly impact on the athlete's speed. In light of these findings, the results of the analyses of correlations of LBM in the athletes studied with race times (a high level of LBM is statistically significantly correlated with longer race time) seem to be interesting. This might suggest that substantial muscle hypertrophy in speed climbing and, consequently, increased body mass (also negatively correlated with race time) may lead to worse sports skill level of the athlete. Furthermore, with high correlations (negative) between body height and race time, the female climbers with greater body size can achieve poorer results in speed climbing. Greater body dimensions can have a negative effect on relative indices of strength and power. As results from previous studies, relative strength can substantially improve chances to achieve high level of achievement in climbing sports (Watts et al., 1993; Ruchlewicz et al., 1997; Mermier et al., 2000; Watts, 2004; Sheel, 2004; Rokowski & Staszkiewicz, 2010) and represents a manifestation of the climbing talent (Ruchlewicz et al., 1997). Therefore, it seems that among the somatic characteristics of female climbers, the biggest effect on the level of achievement in the sport is from the morphological muscle structure: high percentage of fast-twitch fibres per relatively low muscle mass. Therefore, it can be suggested that the main and the most important somatic aptitude in this competition is quality (composition) of muscle fibres rather than their quantity (muscle mass).

Conclusion

The findings of this study lead to the following conclusions:

1. Our results suggests that the specific body build of female speed climbers can determine race time to a greater extent compared to maximal anaerobic power of the lower limbs.
2. Race time in female sport climbers can be determined by the level of body size of the athlete. Insignificant body dimensions can be conducive to the achievement of better race times in speed climbers.
3. It can be indicated that a high level of maximal alactic anaerobic power of the lower limbs of female speed climbers has an effect of race time.

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