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ANAEROBIC POWER IN SPORTS

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Abstract. *The aim of the present study is to determine the anaerobic power of men of similar age representing different sports disciplines. Professional athletes representing the following sports participated in the study: soccer (n=15, PS), martial arts (n=12, MA), weightlifting (n=15, WL), powerlifting (n=15, PL), middle- and long distance running (n=12, DR), race walking (n=14, RW), and recreational soccer (n=15, RS). After recording personal and somatic data, the subjects performed a 3-minute warm-up followed immediately by a 30 seconds cycloergometric Wingate test. The following variables of anaerobic power were calculated: total external work (TEW-KJ/30s), maximal power (Pmax-W/kg), mean power (Pmean-W/kg), fatigue index (FI- %). It was shown that the examined groups differed in body weight (F=13.560, p<0.001), body height (F=3.342, p<0.01) and BMI (F=28.868, p<0.01). There were also significant differences in the TEW range (F=5.764, p<0.001), Pmax (F=2.807, p=0.013) and FI=4.942, p<0.001) and no intergroup difference in the Pmean range. In conclusion, it should be pointed out that various types of sports training develop in the various degree different components of anaerobic power, however they develop similarly its average value.*
Keywords: *anaerobic power, sport; training.*

Introduction

The classic 30-second Wingate test is often used to assess the so-called anaerobic power, which reflects the maximum rate of ATP resynthesis (Minahan et al., 2007). The analysis of the mechanical power developed during this test allows to distinguish four components of anaerobic power: total external work performed in 30s (TEW), maximal power (Pmax), mean power (Pmean) and fatigue index (FI). TEW and Pmean are connected with an anaerobic capacity, maximal power expresses maximal power output and fatigue index reflects

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anaerobic endurance. Because the high correlation between maximal power developed during the 30 second duration of this test with phosphocreatine and muscle acidosis (Cheetham et al., 1986; Bogdanis et al., 1995) was described, it is reasonable to use the mechanical variables obtained in the Wingate test as anaerobic power indicators. Anaerobic power plays an important role in sport and is a good indicator of the physical performance in many sports' disciplines (Hoffman et al., 2017; Janot et al., 2015; Roczniok et al., 2016). A significant part of its development is genetically conditioned (Lortie et al., 1986), but the type and intensity of the applied sports training has a great share in its stimulation. A high level of anaerobic power was recorded in volleyball and basketball groups (Popadic Gacesa et al., 2009), weightlifters (Pilis et al., 1997), powerlifters and wrestlers (Hakkinen et al., 1984) but low among long distance runners (Skinner et al., 1986) and handball players (Popadic Gacesa et al., 2009). The above-mentioned types of anaerobic power among various sports' groups are supported by laboratory tests, which indicate that strength training (Larid et al., 2016; Zając et al., 1999) and plyometric training (Asadi, 2015) have a significant influence on the increase of anaerobic power. Taking into account the above data in the presented work, it was decided to compare the anaerobic power indicators of several sports groups differing in the nature of their training. The comparisons include professional athletes: soccer, martial arts, weightlifting, powerlifting, middle and long distance running, race walking and the group of recreationally trained soccer players.

Materials and Methods

The study involved seven athletic groups of a similar age. Professional athletes were represented by: soccer (n=15, PS), martial arts – taekwondo and brazilian jiu-jitsu (n=12, MA), weightlifters (n=15, WL), powerlifters (n=15, PL), middle and long distance runners (n=12, DR), race walkers (n=14, RW). Recreational sport was represented by soccer players (n=15, RS). Professional athletes represented a similar sports' level (II, I and master sport class) but the recreational soccer players had no any sport class. The length of applied sports training in all groups ranged between 2.5 and 14 years. Despite such a large dispersion of the training experience, the subjects represented a similar level of sports performance reaching the first and the master class level, and therefore the subjects with extremely high or low training experience were not rejected from the research.

All subjects have not used medications and they reported to the laboratory in the morning, 2 hours after a light meal. At the first stage of the study age, body mass (BM) and body heigh (BH) were recorded, while BMI index was calculated. At the next stage a specific 5-minute long warming-up was conducted on a cyclo-ergometer (brand, Excalibur Sports). Then on the same cycloergometer the 30-second Wingate test was performed with resistance set at 0.075kp x kg^{-1}BM. After ending the test total external work (TEW-KJ/kg), maximal power output (Pmax-W/kg), mean power (Pmean-W/kg), and fatigue index (FI-%) were calculated.

The study was conducted with the permission nr KB-1/2013 of Ethical Committee of Jan Długosz University in Częstochowa.

In first stage of statistical preparation arithmetic means and standard deviations of obtained results were calculated. In next stage one-way analysis of variance with post hoc Tukey test were used. The level of statistical significance was set at $p<0.05$.

Results

The respondents of similar age (Table 1) differed in body weight ($F=13.560$, $p<0.001$), body height ($F=3.342$, $p<0.01$) and BMI ($F=28.868$, $p<0.001$).

Table 1 **Age and somatic variables of tested athletes**

Group	**Age [years]**		**BM [kg]**		**BH [cm]**		**BMI [kg*m^{-2}]**	
	x	±SD	x	±SD	x	±SD	x	±SD
PS, n=15	22,60	4,01	76,07	7,92	182,13	6,28	22,92	1,95
RS, n=15	23,47	4,78	74,67	7,84	178,60	4,44	23,41	2,21
MA, n=12	24,12	7,28	72,34	9,41	173,11	7,15	24,11	3,03
WL, n=15	22,80	2,96	79,85	15,75	174,40	8,54	26,02	3,20
PL, n=15	25,67	5,45	94,36	13,20	175,60	9,79	30,45	2,16
DR, n=12	22,81	6,02	68,03	3,70	181,00	3,40	20,72	1,18
RW, n=14	22,21	7,16	62,65	8,54	174,28	6,71	20,60	2,42
F	0,670		13,560		3,342		28,868	
p<	0,674		**0,001**		**0,01**		**0,001**	

PS – soccer players; RS – recreational soccer players; MA- martial arts athletes; WL – weightlifters; PL - powerlifters; DR - middle- and long distance runners; RW – race walkers

The results of post-hoc analysis of somatic variables (Table 3) show that PL achieved significantly higher body mass than the other groups. PS, on the other hand, were higher than MA and RW ($p<0.01$) as well as WL and PL ($p<0.05$). PL had significantly higher BMI in comparison to other sports groups ($p<0.001$).

Table 2 **Anaerobic power variables of the tested athletes**

Group	TEW [kJ/30s]		Pmax [W/kg]		Pmean [W/kg]		FI [%]	
	x	±SD	x	±SD	x	±SD	X	±SD
PS, n =15	19,31	4,25	14,21	1,85	8,46	1,40	65,52	16,19
RS, n=15	18,02	1,70	13,38	2,49	8,21	1,03	54,91	8,03
MA, n=12	17,29	2,65	12,61	1,02	8,10	0,79	56,02	6,54
WL, n=15	17,99	3,76	14,21	2,70	7,61	1,16	68,37	10,57
PL, n=15	21,64	4,43	13,98	2,37	7,67	0,90	64,23	6,94
DR, n=12	16,31	1,97	12,49	2,29	8,36	0,76	54,19	16,14
RW, n=14	14,62	2,80	11,50	1,51	7,87	0,94	51,18	7,94
F	5,764		2,897		1,558		4,942	
p<	**0,001**		**0,013**		0,169		**0,001**	

PS – soccer players; RS – recreational soccer players; MA- martial arts athletes; WL – weightlifters; PL - powerlifters; DR - middle- and long distance runners; RW – race walkers

Table 3 **Results of intergroup statistical comparisons with the post hoc test**

Groups	Age [years]	BM [kg]	BH [cm]	BMI [kg/m^2]	TEW [kJ/30s]	Pmax [W/kg]	Pmean [W/kg]	FI [%]
PS-RS	NS	NS	NS	NS	NS	NS	NS	0.05
PS-MA	NS	NS	0.01	NS	NS	0.05	NS	NS
PS-WL	NS	NS	0.05	0.01	NS	NS	NS	NS
PS-PL	NS	0.001	0.05	0.001	NS	NS	NS	NS
PS-DR	NS	0.01	NS	NS	NS	NS	NS	NS
PS-RW	NS	0.001	0.01	0.05	0.01	0.001	NS	0.01
RS-MA	NS	NS	0.05	NS	NS	NS	NS	NS
RS-WL	NS	NS	NS	0.05	NS	NS	NS	0.001
RS-PL	NS	0.001	NS	0.001	0.01	NS	NS	0.01
RS-DR	NS	0.05	0.05	0.001	NS	NS	NS	NS
RS-RW	NS	0.001	NS	0.01	0.001	0.05	NS	NS
MA-WL	NS	NS	NS	NS	NS	NS	NS	0.01
MA-PL	NS	0.001	NS	0.001	0.01	NS	NS	0.01
MA-DR	NS	NS	0.01	0.01	NS	NS	NS	NS
MA-RW	NS	0.05	NS	0.01	0.05	0.01	NS	NS
WL-PL	NS	0.05	NS	0.001	0.05	NS	NS	NS
WL-DR	NS	0.01	0.05	0.001	NS	NS	NS	0.05
WL-RW	NS	0.001	NS	0.001	0.05	0.01	NS	0.001
PL-DR	NS	0.001	NS	0.001	0.001	NS	NS	0.05
PL-RW	NS	0.001	NS	0.001	0.001	0.01	NS	0.001
DR-RW	NS	NS	0.01	NS	NS	NS	NS	NS

NS – no significant

Analysis of variance showed (Table 2) that the sports groups differed also in the TEW range (F=5.764; p<0.001), Pmax (F=2.897; p=0.013) and FI (F=4.942; p <0.001). Post hoc analysis showed (Table 3) that TEW achieved by PL was significantly higher than that found in the groups: RW and DR (p<0.001), RS and MA (p<0.01), and WL (p<0.05). The high Pmax values achieved by the PS group differed from the results achieved by RW (p<0.001) and MA (p<0.05) and the Pmax of the WL group were higher than RW (p<0.01). However, the highest FI values were achieved in the WL group and they were significantly higher than in the groups: RW and RS (p<0.001), MA (p<0.01), and DR (p<0.05). The other comparisons of post hoc results are presented in Table 3.

Discussion

The highest body mass was achieved by PL and the tallest were in PS group. Significant differences in the scope of these two somatic variables were not related to the age of the respondents, because all subjects' groups were similar in this respect and BM and BH significantly influenced the BMI index. This variable in the initial stages of almost every kind of training is reduced due to the decrease in fat content in the body (Milanović et al., 2015) and also during later stages of endurance training, while in the case of strength training BMI increase is due to the appearance of hypertrophy of the skeletal muscles. The highest BMI values in the present studies were achieved in the PL group and they were significantly higher than in the other groups (p<0.001), even in those with strength training (WL and MA). The effect of strength training resulting in significant skeletal muscle hypertrophy was especially significant among WL, whose BMI significantly exceeded this variable in the PS, RS, DR and RW groups, and reached a similar value to that occurring in the MA group. Strength training among WL is practiced in a smaller volume than by PL, as the athletes of the first group have to devote a significant amount of time to learning and improving the technique of performing classical exercises, therefore the range of their muscle hypertrophy is to a lesser extent than in PL. MA's athletes also devote more training time to learning and improving the technical elements of a sports fight and a less time, although still statistically significant for strength exercises; this also caused a considerable muscle hypertrophy effect among them. These effects of strength exercises on the increased development of the muscular system were manifested in the fact that the BMI index in WL and MA groups did not differ statistically. In MA group, muscle hypertrophy occurred to a significant extent, because BMI of these athletes was higher than in DR and WR groups (p<0.01), where these athletes incorporate strength exercises into their trainings in a specific form and in a significantly limited amount. However a relatively small number of strength exercises and exercises that affect the development of power are carried out in PS and RS training, which stimulate the development of strength and muscle mass of these athletes to a significant extent. Therefore, the BMI in PS group was significantly higher in comparison with RW group ($p<0.05$) and in RS group was significantly higher than in DR group ($p<0.001$), and in RW group ($p<0.01$). Somatic determinants in competitive sports are given a significant role. It is even observed that in running and jumping disciplines, and in soccer, slim body shape (low BMI) may be an important factor supporting the development of sports level (Rielly et al., 2000; Pilis et al., 2013), what cannot be said in relation to strength competition.

Following the somatic changes, intergroup differences in TEW, Pmax and FI range were observed. The absolute value of TEW does not add much knowledge when comparing the anaerobic power of athletes from different disciplines present in this study, because in a significant part it is only a reflection of the impact of body mass on the obtained values of this variable. Interestingly, the athletes of the studied groups did not differ in Pmean size, despite the significant somatic (BM) differences and the nature of their training. Strength training (Pilis at al., 1997) and soccer training (Milanović et al., 2015) in a large and significant part caused the development of anaerobic power and in this study led to significant development of Pmax in WL and PS groups. At the same time, these types of training did not lead to the development of anaerobic endurance, resulting in high FI values in both groups. The reverse relation between Pmax and FI was observed, in DR and RW groups, whose training to a small extent stimulated maximal power and more strongly shaped anaerobic endurance. Physiological adaptation to such trainings boils down to the fact that in the both groups of athletes low Pmax and FI values were achieved, which was confirmed in the available literature (Popadic Gacesa et al., 2009; Skinner, 1986). Globally, it can be concluded that the different types of applied sports training led to the formation of other patterns of anaerobic power. Strength training and power development training increased the maximal anaerobic power, which decreased faster in time (because athletes were not able to maintain it at a high level) than in endurance training groups, in which maximal anaerobic power were at a lower level. As a result, during the 30s Wingate test Pmean reached a similar level in all investigated in the present study athletes' groups. It should be assumed that in case of longer tests of anaerobic power evaluation, endurance trained athletes would achieve higher Pmean values than strength trained athletes, which is confirmed by practical observation of the exercise capacity of various sports groups. The basis for PS, RS, DR and RW training is high and mainly medium intensity running (Milanović et al., 2015; Larsen, 2003), but in soccer training there is also anaerobic power development, while in runners and race walkers training development of aerobic power is based on high oxygen uptake (Maldonaldo et al., 2002). In the other studied groups i.e. in WL and PL, anaerobic power is developed to a high degree and MA in the middle range as a result of the use of specialized training for these sport disciplines. The comparison of the anaerobic power variables in soccer groups with different sports level showed slight differences between PS and RS and this concerned only the FI indicator ($p < 0.05$). This means that RS athletes were also to some extent trained, as evidenced by the fact that they achieved similar Pmax and Pmean values in relation to other studied groups. It should also be taken into account that, apart from the type of training, the genetic factors (Lortie et al., 1986) and the specificity of the mechanical work performed during the test evaluating this feature have a significant influence on the values of the obtained anaerobic power (Hilliard et al., 1991; Williams & Nute, 1983). To improve proper technique of movement it is recommended the compensatory exercises are included in order to reduce muscle imbalance (Horbacz et al., 2013). For all groups in the presented studies, the Wingate test used to assess anaerobic power was unspecific, as none of these groups of athletes trained on cycloergometer or bicycles. Thus, in this respect, the test conditions for all studied athletes were comparable.

Conclusion

1. The type of used sport training determines the quality of changes in anaerobic power parameters and somatic conditions.
2. Strength training increases maximal anaerobic power, but to a lesser extent it develops anaerobic endurance.
3. Endurance training to a lesser extent develops maximal anaerobic power with a significant impact on the development of anaerobic endurance.
4. In order to better understand the mutual relationships between the various components of anaerobic power, it is recommended to carry out its evaluation tests with varying durations.

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