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Determinant factors of aerobic and anaerobic power in martial arts

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Abstract

Background and Study Aim. The body's ability to undertake physical effort is highly variable and depends on many factors. Therefore, the aim of present stady was knowledge about factors what determine the development of anaerobic power (AnP) and aerobic power (AP) in people practicing martial arts and in untrained persons.

Material and Methods. At the commencement of this study a dietary composition of 8 Brazilian jiu jitsu athletes, 4 taekwondo athletes (SG) and 10 students (CG) was recorded. Then both groups performed Wingate test (WT) to determine AnP and later a cycle ergometer test (ET) was performed during which AP, pulmonary and circulatory variables were recorded. Afterwards a correlation between AP and AnP indicators was performed. Then AP and AnP indicators were also correlated with the oxygen consumption (VO_2), oxygen debt (OD), the value of energy expenditure (EE), the ingredients of the diet (UD) and somatic indicators (SP) separately in each group.

Result. The AP reached at anaerobic threshold (APAT) and aerobic power at maximal load (APML) correlated with numerous indicators of AnP indicators in the SG group, whereas in the CG group the correlations were few and concerned APML and AnP variables such as total work (Wt) and mean power (Pmean). Additionally AP and AnP showed more frequently significant correlation with VO_2, OD, EE, UD and SP in the SG group than in CG group.

Conclusion. Studies have shown that training in martial arts not only causes specific adaptation changes in the body but also improves the functional interdependence.

Key words: diet • correlations

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Introduction

The best indicator of physical performance is the amount of performed work or the size of power output during a specific physical effort whether it will be at work or in certain types of sports. Such specific tests of physical performance evaluation may be: Cooper test evaluating specific running performance [1], cycle ergometer trial evaluating specific physical performance of cyclists [2], a specific test for judo competitors developed by Sterkowicz [3], or the height of a volleyball player jump (in two jumping capacity tests) [4]. Such specific evaluation is not always technically feasible or it is not necessary to perform and then overall physical performance is evaluated. Usually these physical performance tests assess aerobic capacity, which outside competitive sport are often used for evaluation in medicine (cardiology, pulmonology, physiotherapy). In elite sports through not proper sports training or in extreme ambient conditions may occur chronic or acute damage to the body. An example of overburdening the cardiovascular system may be too intense weight training, during which a trained bodybuilder has recorded increase in blood pressure up to 480/350 mm Hg [5]. Dysfunctions were also observed in the respiratory system in case of endurance athletes, where intense breathing took place under different temperature conditions [6]. Such repetitive and excessive burden may lead to a gradual or sudden reduction of physical capacity and tracking its changes may be an indication of health recovery and in the case of active sports training shows increase in physical capacity, helping in achieving satisfactory results in sport. Decreasing physical performance in sport's training indicates overtraining, which can change into fatigue and be the basis for upcoming diseases.

It is known that the overall physical performance is determined by factors such as the efficiency of the various body systems, physical, mental and environmental variables and the nature of training [7]. Taking into account the above suggestions the aim of present stady was knowledge about factors what determine the development of anaerobic power (AnP) and aerobic power (AP) in people practicing martial arts and in untrained persons.

Material and methods

The study was approved by the Bioethics Research Committee of Jan Dlugosz University in Czestochowa, Poland.

Subjects

Twelve martial arts athletes (SG) (4 TKD athletes and 8 BJJ athletes) and ten untrained students (CG) with comparable age were studied. The martial arts athletes had an average training experience of 3.65±2.44 years and the frequency of training sessions was 3-5 times per week each of 1.5 h duration.

Procedures

For a period of three days prior to the study participants wrote down their diets, which were later analyzed by a computer program Dieta-5. The program details the value of the caloric content of proteins, fats, carbohydrates, water, minerals and vitamins. After determining the age of the respondents, body height (BH) was measured, and body weight (BW) and its composition was recorded using the body composition analyzer, Tanita BS 418 - MA. The body composition included fat (BF), lean body mass (FFM) and the body water (TBW). In addition, weight-height indices such as BMI, Quetelet, Rohrer and Slim index were calculated. In the next stage of research the Wingate anaerobic power test (WT) was performed and the following variables were determined: total work performed during the 30s (Wt), maximal power (Pmax), mean power (Pmean), minimal power (Pmin), total power slope (Ts) and rate of fatigue (Rf). Then, after a four-hour break and after 10 minutes seating, heart rate (HR) was measured during rest (R) in all subjects. Further on, while a face mask was tightly secured in place and connected with quick breath analyzer (Ergo Card), the following pulmonary variables were recorded: maximum pulmonary ventilation per minute (VE), oxygen consumption per minute (VO_2), carbon dioxide output per minute (VCO_2), respiratory exchange ratio (RER) and cardiac output (CO).

Afterwards the participants have performed a cycle ergometer test (ET), which consisted of pedaling at a rate of 60 rpm with an initial load of 60W. Thereafter every 3 minutes the load has been increased by 30W, until the individual maximum load (ML) was reached. At every load change all previously mentioned parameters were recorded and calculations were performed.

An anaerobic threshold (AT) was calculated using the VE dynamic stress changes method proposed by Beaver et al. (1986) and it was expressed in watts (W). The statistical analyzes has taken into account those parameters recorded during R, AT and with individual maximum load (ML). During the first 5 minutes after the completion of ET volume OD was measured and it was calculated in a traditional way as the difference between total oxygen uptake during 5-minute recovery period and total resting oxygen uptake at 5 minute rest before the exercise. Minute's EE during ET at R, AT and ML was calculated according to the modified Weir [8] equation, EE = (3.94 × VO_2) + (1.1 × VCO_2); wherein EE is energy expenditure (kcal×min^{-1}), VO_2 is the size of the oxygen uptake (l×min^{-1}), VCO_2 (l×min^{-1}), is the volume of carbon dioxide excretion.

Statistical Analysis

The statistical significance of differences between the two groups in terms of body weight and body composition, VO_2max, OD, EE-ML and the ingredients of UD was calculated using the "t" Student test. Pearson linear correlation coefficients "r" was calculated between the aerobic power reached during ET, at AT and ML, and anaerobic power indices assessed during WT. Further the AP and AnP indices were correlated with: VO_2 determined at rest (VO_2-R), VO_2 determined at AT (VO_2-AT), and VO_2 determined at ML (VO_2-ML), OD, EE, SP, and ingredients of UD. The level of significance was set at 0.05.

Results

The competitors did not differ with age and somatic variables (Table 1). In SG were observed significantly higher values of: APAT, APML, Wt, Pmean, VE, VO_2-AT, VO_2max-ML (l×min^{-1}), OD, EE-ML in comparison to CG. Comparison performed between both groups has shown that in the diet of SG was higher content of animals protein and magnesium, but in the diet of CG was observed higher content of sodium and vitamin E.

It has been shown that the APAT and APML in SG correlated with the following anaerobic

Table 1. Somatic characteristic of- subjects; SG, n=12; CG, n=10

Variables	Groups	x	SD	t	p<
Age [years]	SG	24.08	4.72	1.973	0.071
	CG	21.30	1.16		
Body height [cm]	SG	173.59	7.66	−0.761	0.456
	CG	175.72	4.62		
Body mass [kg]	SG	72.87	8.75	0.759	0.457
	CG	69.83	10.09		
BMI [kg×m^{-2}]	SG	24.18	2.56	1.326	0.200
	CG	22.60	3.04		
Quetelet idex [g×cm^{-1}]	SG	419.47	44.18	1.058	0.303
	CG	397.18	54.67		
Rohrer index [g×cm^{-3}]	SG	1.40	0.17	1.447	0.164
	CG	1.29	0.18		
Slim index [cm^3×√kg^{-1}]	SG	41.65	1.72	−1.513	0.146
	CG	42.83	1.92		
BF [%]	SG	15.15	3.80	0.569	0.576
	CG	14.05	5.25		
BF [kg]	SG	11.26	3.82	0.521	0.608
	CG	10.27	5.14		
FFM [%]	SG	84.82	3.82	−0.571	0.575
	CG	85.93	5.24		
FFM [kg]	SG	61.61	5.90	0.846	0.408
	CG	59.56	5.33		
TBW [%]	SG	62.08	2.80	−0.578	0.570
	CG	62.90	3.82		
TBW [kg]	SG	45.09	4.33	0.840	0.411
	CG	43.60	3.92		

performance indicators: Wt, Pmax, Pmean [W, W×kg^{-1}], and Pmin (Table 2), on the other hand in CG these correlations occurred less frequently and dealt with APML vs. Wt and vs. Pean [W, W×kg^{-1}] (Table2).

Table 2. Pearson correlation coefficients "r" between mechanical indices of aerobic power and anaerobic power; SG, n=12; CG, n=10

Aerobic power	Groups	Wt [KJ]	Pmax [W]	Pmean [W]	Pmean [W × kg^{-1}]	Pmin [W]
APAT [W]	SG CG	0.843 xxx NS	0.622 x NS	0.844 xxx NS	0.583 x NS	0.763 xx NS
APML [W]	SG CG	0.893 xxx 0.751 xx	0.609 x NS	0.893 xxx 0.752 xx	0.711 xx 0667 x	0.755 xx NS

x-p<0.05; xx-p<0.01; xxx-p<0.001;

Such AnP indicators as: Wt, Pmax, Pmean [W, W×kg^{-1}], Pmin and AP indicators, i.e. APAT and APML in SG correlated with VO_2-R, VO_2-AT, VO_2-ML, OD, EE-ML. However, among these correlations were several insignificant dependencies, i.e.: Pmax vs. VO_2-AT, Pmax vs. OD, and Pmean [W×kg^{-1}] vs. OD, as well as Pmin vs. OD (Table 3). The CG correlations in this regard were much less frequent and concerned only Pmin vs. VO_2-ML, OD, EE and APAT vs. VO_2-R, VO_2-AT, VO_2-ML, OD, EE-ML.

Table 4 illustrates dependencies of AP and AnP with SP. AnP variables such as: Wt, Pmean [W] Pmin have correlated with numerous somatic parameters in SG and CG. On the other hand Pmax, APAT and APML have correlated with BW, FFM [kg], TBW [kg], Quetelet index, and additionally Pmax correlated with FAT [kg] only in SG.

There was also a statistically significant correlation coefficients of Wt vs. animal protein in the diet - r = 0.619 (p <0.05), APML vs. the amount of magnesium in the diet – R=0.740 (p<0.01) in SG and APAT vs. the amount of potassium in the diet r = –0.638 (p <0.05) with respect to CG.

Discussion

This study has shown that APAT and APML indicating aerobic power in SG correlated with Wt, Pmax, Pmean [W, W × kg−1] and Pmin have characterized anaerobic power, while in the untrained CG group these correlations were less frequent and concerned only the APML from Wt, Pmean [W, W × kg−1]. This suggests that in case of trained group of athletes aerobic and anaerobic pathways resynthesis of energy are coordinated to a greater extent than in untrained persons. A similar lack of correlation between the anaerobic power of upper and lower extremities in the group of swimmers observed Stanula [9], which indicates a different degree of post-exercise adaptation of various parts of the body. This evidence suggests that post-training power changes are a complicated process, that training improves them and that in order to determine changes in the body's physical performance, it is necessary to make a lot of physical capacity tests of as many body part as possible.

Linear relationship between the oxygen uptake and developed power output is a fundamental

Table 3. Pearson correlation coefficients "r" between mechanical indices of aerobic power and: anaerobic power, VO_2, oxygen debt and energy expenditure; SG, n=12; CG, n=10

Mechanical variables	Groups	VO_2-R l × min^{-1}	VO_2-AT l × min^{-1}	VO_{2max}-ML l × min^{-1}	Oxygen debt l – 5min^{-1}	EE-ML kcal × min^{-1}
Wt [kJ]	SG CG	775 xx NS	0.697 xx NS	0.775 xx NS	0.626 x NS	0.900 xxx NS
Pmax [W]	SG CG	0.553 x NS	NS NS	0.579 x NS	NS NS	0.590 x NS
Pmean [W]	SG CG	0.777 xx NS	0.697 x NS	0.880 xxx NS	0.626 x NS	0.900 xxx NS
Pmean [W×kg^{-1}]	SG CG	0.584 x NS	0.712 xx NS	0.616 x NS	NS NS	625 x NS
Pmin [W]	SG CG	0.767 xx NS	0.594 x NS	0.699 xx 0.682 x	NS 0.610 x	0.686 xx 0.639 x
APAT [W]	SG CG	0.752 xx 0.695 x	0.848 xxx 0.908 xxx	0.765 xx 0.790 xx	0.666 xx 0.624 x	0.680 xx 0.806 xx
APML [W]	SG CG	0.733 xx NS	0.782 xx NS	0.891 xxx NS	0.602 x NS	0.874 xxx NS

x-p<0.05; xx-p<0.01; xxx-p<0.001;

Table 4. Pearson "r" correlation coefficients between aerobic and anaerobic variables and somatic indices; SG, n=12; CG, n=10

Variables	Groups	BW [kg]	BF [%]	BF [kg]	FFM [%]	FFM [kg]	TBW [%]	TBW [kg]	BMI [kg×m^2]	Quetelet Index [g×cm^{-1}]	Rohrer Index [g×cm^3]	Slim Index [cm×$^3\sqrt{}$kg^{-1}]
Wt [kJ]	SG	0.930^{xxx}	NS	0.704	NS	0.922^{xxx}	NS	0.923^{xxx}	0.644^{xx}	0.861^{xxx}	NS	NS
	CG	0.631^{x}	0.687^{x}	0.673^{x}	−0.687^{x}	NS	−0.687^{x}	NS	0.701^{x}	0.687^{x}	0.698^{x}	−0.691^{x}
Pmax [W]	SG	0.797^{xx}	NS	0.610^{x}	NS	0.786^{xx}	NS	0.784^{xx}	NS	0.707^{xx}	NS	NS
	CG	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Pmean [W]	SG	0.930^{xxx}	NS	0.703^{xx}	NS	0.923^{xxx}	NS	0.924^{xxx}	0.643^{xx}	0.861^{xxx}	0.698^{xx}	−0.691^{xx}
	CG	0.653^{x}	0.686^{x}	0.673^{x}	−0.686^{x}	NS	−0.686^{x}	NS	0.701^{x}	0.689^{x}	NS	NS
Pmin [W]	SG	0.698^{xx}	NS	NS	NS	0.689^{xx}	NS	0.689^{xx}	0.635	0.723^{xx}	NS	NS
	CG	0.750^{xx}	0.699^{x}	0.715^{x}	−0.696^{x}	0.725^{x}	−0.699^{x}	0.723^{x}	0.742^{xx}	0.757^{xx}	0.705^{x}	−0.707^{x}
APAT [W]	SG	0.783^{xx}	NS	NS	NS	0.861^{xxx}	NS	0.862^{xxx}	NS	0.684^{x}	NS	NS
	CG	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
APML [W]	SG	0.790^{xx}	NS	NS	NS	0.840^{xxx}	NS	0.841^{xxx}	NS	0.675^{xx}	NS	NS
	CG	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

x-p<0.05; xx-p<0.01; xxx-p<0.001

concept occurring in applied physiology. However it turns out that this basic correlation can be modified, because Beaven et al. [10] showed that VO_2 changes at 88.93% (R^2 = 0.8893) are explained by the increasing power output during the graduated cycle ergometer test performed with concentric work of arms, while for the eccentric working of the upper limbs R^2 = 0.5923, and the correlation was significantly weaker than the previously cited. The surveyed subjects have performed concentric work every day and the eccentric test was performed only for experimental purposes. Therefore we must assume that they performed eccentric test with much poorer technique and with lower mechanical efficiency as it was shown in the cited paper. These data therefore indicate that a change in the nature of work and the deterioration of exercise techniques affect the strength of the correlation between oxygen uptake and power output. Our data indicate that the volume of VO_2-R, VO_2-AT, VO_2-ML correlated significantly more frequently with indicators of AP and AnP in a trained SG than in untrained CG. Beaven et al. [10] further suggests that the level of training of muscles can modify this relationship. Applying this comment to the results of our study, we can conclude that indeed both groups did not differ in somatic variables but the SG was better trained, because it reached higher values APAT, APML during the ET and Wt as well as Pmean while doing WT. Thus, correlations between oxygen uptake and power output during exercise can be reasonably explained by the better trained SG and the resulting higher mechanical efficiency of the subjects in Beaven et al. [10] study (the coefficient of work's mechanical efficiency was not calculated in our study). This also may have a significant impact on the incidence of correlation between AP and AnP. Significant correlations occurring in SG between AP as well as AnP and EE-ML were almost identical to the relationships appearing between AP as well as AnP with VO_2max-ML, while in the CG significant correlations of EE-ML were observed only with Pmin and with the APAT. It can be assumed that martial arts training led to stimulate both aerobic and anaerobic metabolism.

Analysis of relationships between somatic variables and AP as well as AnP showed that body weight had a significant impact on the size of AnP because in both groups analyzed Wt, Pmax, Pmean, Pmin were significantly correlated with it. Similarly in earlier studies Pilis et al. [11] found in a group of weight lifters a significant correlation between body weight and aerobic maximum power and Pmax, which was assessed with Margaria et al. [12] test. Relatively expressed Pmax showed no relation to body weight. However, in the presented studies size of aerobic power expressed as the APAT and the APML only in the training group correlated significantly with body weight and body composition. Therefore it is concluded that both AP and AnP (regardless of the method of its definition) to a greater extent are determined by the weight size and not by the level of training. In another study Mikkola et al. [13] showed that after 6-12 months endurance-strength military service training and standard diet (3200-3600 kcal × day^{-1}) there was a significant linear relationship between change in AP and changes in body weight, fat mass, fat free mass, waist circumference and visceral fat area and these relationships have become more substantial if training period of the overweight and obese people was lengthening compared with normal-weight subjects. [13]. Cited studies show that body weight and body composition change themself in the coaching process of people trained in varied degree and determine the development of physical fitness and power capacity. Although direct measurements of somatic variables in our study showed no difference between SG and CG, however numerous correlations existing between somatic variables and AP only in SG confirm, that there is an effect of somatic determinants on the power output in this group of athletes. The observed differences of the described correlations of trained individuals in relation to untrained subjects may also be the result of a stronger stimulation of the nervous system that appears in the early stages of the training process and occurring much later, or poorly outlined muscle hypertrophy, affecting the development of muscle strength [14]. These phenomena did not occur in untrained people.

AP and AnP correlations occurring with OD in SG and much less likely to appear such relationships in CG have a theoretical basis corresponding to the fact that the oxygen debt during exercise and size of the anaerobic energy release are closely interrelated. It is true that oxygen deficit is strongly connected with AnP and represents the smaller part incurred oxygen debt [15]. In our study the size of oxygen debt turned out to be predictive not only in relation to the anaerobic power output but also to aerobic output in SG. The strength of such correlations in the non-trained group was far lesser than in SG, what once again shows that the hydrolysis and re-synthesis systems of energy in trained people is more efficient than in untrained.

Only three statistically significant correlations between power output and the diet ingredients among many more possibilities suggest that a type of diet does not always directly influence human physical performance.

Conclusion

Greater AP and AnP, and closer correlation between AP and AnP were observed in a group of athletes, who train martial arts, while in case of untrained persons with the lower power's values this correlation appeared to be weaker. The reasons for the differences in these relationships of both groups are believed to be the body modifications resulting from training, and manifesting an increase and improvement of aerobic and anaerobic metabolism, as well as of the energy expenditure system. The somatic changes that influence the size of the power output can be caused only by the improvement of transduction nervous-muscle system without apparent skeletal muscle hypertrophy.

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