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Differentiation of somatic and efficiency indicators as a sign of athletes' adaptation to efforts of various nature

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Abstract

Background & study Aim: The problem of the work is to search for the relationship between the type (character) of professional training used and the differences in the values of somatic and efficiency indicators of athletes. The aim of the study is knowledge about the diversity of somatic features, body composition and anaerobic power of professional athletes of heterogeneous sports disciplines and students of physical education.

Material & Methods: The study included athletes with second or higher sports classes in the following disciplines: long distance runners (n = 12), powerlifting (n = 12) and martial arts – taekwondo and Brazilian jiu-jitsu (n = 12). Students of physical education (n = 12) constituted the control group. Somatic measurements were made using the Tanita Body Composition Analyzer TBF-300 (Japan). Anaerobic capacity was measured using the Wingate 30 s test on an Excalibur Sport cycloergometer.

Results: Participants of the study differed in such somatic and body composition variables as: body weight, fat content, lean body mass, water content in the body. Intergroup differences in the amount of work done [W], average power [Pmean] and maximum power [Pmax], recorded during the Wingate test, were indicated. A relationship was found between the value of performance and somatic variables and the type of sport practiced.

Conclusions: Applied sports training of various nature can cause significant changes in the bodies of athletes. Physiological and somatic variables can be identifiers indicating different levels of sports preparation of the examined people.

Keywords: aerobic capacity • anaerobic capacity • combat sports • power triathlete • training

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Supramaximal – (med.) stimulus with strength significantly above that required to activate all nerve or muscle fibres in contact with electrode; used when response fibres is desired.

Peak – *noun* the highest point, e.g. Of achievement or fitness [41].

ATP – *abbreviation* adenosine triphosphate [41].

Aerobic capacity – *noun* same as **VO2Max** [41].

VO2Max – *noun* the maximum possible intake of oxygen for aerobic metabolism during exercise [41].

Anaerobic capacity – *noun* the maximum amount of energy that can be produced by anaerobic metabolism [41]

Anaerobic power – *noun* same as **anaerobic capacity** [41].

Exercise intensity – *noun* the degree to which a workout is difficult for the exerciser [41].

Resynthesis – *noun* the synthesis of fresh energy from the breakdown of lactic acid [41].

Performance – *noun* the level at which a player or athlete is carrying out their activity, either in relation to others or in relation to personal goals or standards [41].

Combat sport – *noun* a sport in which one person fights another, e.g. wrestling, boxing and the martial arts [41].

Load – *noun* **1.** a weight or mass which is supported **2.** the force that a body part or structure is subjected to when it resists externally applied forces **3.** the amount of something, usually weight, that a body part can deal with at one time [41].

INTRODUCTION

Achieving high performance in competitive sport depends on genetic and somatic determinants, the use of an optimal diet, as well as a systematic training process tailored to the individual characteristics of the athletes [1-4]. The decisive factors influencing the correctness of the training process in sporting activities, are somatic characteristics and physical performance [5, 1, 6].

Despite the relatively well-recognised somatic determinants of athletes in most sports, there are still few references to levels of fitness and training status that have a significant impact on athletic performance [7, 8]. At virtually any age, it is possible to increase or maintain a high level of physical performance through appropriately planned training [9-12]. Depending on the duration, intensity of the exercise performed and activation of the energy pathways required to perform the exercise, physical capacity is divided into aerobic and anaerobic. Increasing the body's level of adaptation to load and the associated improvement in maximal anaerobic capacity allows the athlete to perform the same or greater effort with less metabolic imbalance [13-15].

It is accepted that the source of energy supply for supramaximal exercise of up to 10 seconds duration is entirely anaerobic processes. Although the breakdown of muscle phosphocreatine can provide energy up to the 30th second of supramaximal exercise, and energy from glycolysis takes place between the 3rd and 45th second of its duration, above the 10th second of such work, aerobic processes of energy re-synthesis are already activated. Unlike aerobic capacity, anaerobic capacity cannot be easily quantified.

Therefore, it has been assumed that the amount of mechanical work performed during supramaximal intensity exercise of 30-60 seconds reflects anaerobic capacity, which results from the breakdown of phosphocreatine and activation of glycolysis. It has also been suggested that a measure of anaerobic capacity is the determination of the maximal cumulative aerobic deficit or the determination of critical power [16], however, the most common methods of diagnosing anaerobic capacity are mechanical ways of determining it. Among these tests, we can distinguish: the 'staircase' running test [17], the Wingate cycloergometric test [18], the vertical jump test [19] or the running test on a mechanical treadmill [20].

Among the aforementioned tests, anaerobic power is the most comprehensively determined by the Wingate test, as it describes maximum anaerobic power, average anaerobic power, minimum anaerobic power and allows the determination of the power drop index. Anaerobic capacity is an important indicator determining sports performance not only during short, high-intensity efforts, but also when performing bursts during endurance efforts. It can also differentiate between athletes in sports disciplines that are similar in terms of the nature of the effort. This is indicated by studies of team game players, where the maximum power measured by the Wingate test reached the highest values among volleyball players at 11.71 ± 1.56 W/kg and basketball players at 10.69 ± 1.67 W/kg, and the lowest among handball players at 8.58 ± 1.56 W/kg [21]. It should be noted that when measuring anaerobic power with the Wingate test, a proper warm-up should be performed beforehand, which results in an increase in peak power, relative peak power and a reduction in the time to reach it by 8.9%, 9.6% and 28.8%, respectively [22].

Determining the current state of training and anaerobic capacity levels provides insight into the extent of metabolic changes induced by a particular type of training (strength and endurance) and an assessment of the body's adaptation to these efforts [14], although these are not always associated with positive health conditions [23]. However, there are also reports indicating that correctly conducted training, both strength and endurance, significantly improves cardiovascular fitness, adapting it to the specific effort in strength, endurance and combat sports [24, 25].

The scope of the study therefore included three sports, differing in the nature of the effort exerted during competition and the energy resynthesis pathways prevalent in these conditions, expecting that there would be major differences in body composition, somatic, functional and exercise characteristics between athletes participating in sports of this nature. It should be presumed that they occur at different intensities, depending on the time of influence of training stimuli on the athletes' organisms and may, in addition to predisposition, be the cause of adaptive changes.

The aim of the study is knowledge about the diversity of somatic features, body composition and anaerobic power of professional athletes of heterogeneous sports disciplines and students of physical education.

MATERIAL AND METHODS

Participants

The study included a group of athletes with second or higher sport classes in the following disciplines: athletic long-distance running, among which there was 1 athlete running 800 m and 1500 m and the others were runners at distances of 5000 and 10000 m (n = 12), power triathlon (n = 12) and combat sports – taekwondo and Brazilian jiu-jitsu (n = 12). In addition, a group of physical education students practising recreationally (n = 12) was also studied as a control group. All study participants were randomised with regard to training length, weight and body height. In sports groups, athletes were recruited from among those with no lower than second sport class in the discipline they practised (including athletes representing the country in international competitions – European and World Cups, European Championships, World Championships, Olympic Games). The groups of athletes participating in the study represented disciplines that differed fundamentally in the nature of the physical efforts performed. These were endurance (long-distance runners), strength (power triathletes) and strength and endurance (combat sports athletes). Although students of physical education did not undergo targeted sports training, they were subjected to efforts of varying nature and duration as part of the study programme at the Jan Dlugosz University in Czestochowa, Poland.

All subjects, in accordance with the Declaration of Helsinki, were informed about the purpose, conduct and possible risks, and the possibility of opting out of the study at any stage without giving a reason. Approval for the study was obtained from the Research Bioethics Committee operating at the Jan Dlugosz University in Czestochowa (Resolution No. KB-1/2013 of the Research Bioethics Committee of 7 May 2013).

After learning all the information, the subjects gave written consent to participate in the experiments. They were informed about the procedure of the anthropometric, body composition and exercise tests and the management during and just after their completion, and a few days beforehand about how to prepare for the measurements.

Study design

The examinations of each group took place on a different date and began with measurements of somatic characteristics, body composition and exercise physiological and biochemical indices.

Somatic examination and body composition

Initially, age was determined by interview and body height (BH) of each subject was measured using an anthropometer. Body Mass (BM) and body composition were determined using the Tanita Body Composition Analyzer TBF-300 (Japan), year of manufacture 2013. Total Body Fat (BF), Free Fat Mass (FFM), Total Body Water (TBW), and Body Mass Index (BMI) were also determined in this study.

Performance test and experimental procedure

After completing the somatic and body composition measurements, the subjects performed a warm-up on a cycloergometer with a load of 100 W for a period of 3 minutes. Afterwards, with maximum mental concentration for a period of 30 seconds, they performed an anaerobic capacity assessment test (Wingate test) with a load selected individually to the subject's body weight according to the formula: W = 0.075 × BM [26], where: W – load [kp]; 0.075 – empirically calculated coefficient; BM – body mass [kg]. The same conversion factor of 0.075 was used for each group of subjects in order to maintain a similar selection of load, although there are recommendations for its differentiation depending on the state of training of the organism. The test was performed on an Excalibur Sport cycloergometer and the moment of starting the test was the moment when the tested athlete reached 100 rpm.

A computer system linked to this cycloergometer recorded the following variables during and after the test: amount of work performed (W) during 30 s [kJ], [kJ/kg body weight]; maximum power (Pmax) [W], [W/kg m. c. c.]; average power (Pmean) [W], [W/kg m. c.]; minimum power (Pmin) [W], [W/kg m. c.]; time to reach maximum power [s]; rate of power loss between maximum and minimum power WSM = (Pmax – Pmin)/t [W/s], [%]. Resting values and values reached at maximum load were considered for statistical calculations.

Statistical analysis

The results obtained were presented using basic descriptive statistics: arithmetic mean (M); standard deviation (SD); F-Snedecor statistics, result of the analysis of variance (*F*) Intergroup differences between somatic variables and anaerobic power indices were calculated by univariate analysis of variance using Tukey's post hoc test. Values at p<0.05 were considered significant.

RESULTS

Somatic characteristics and body composition of the groups

The univariate analysis of variance used showed that the subjects differed in: body weight (F = 16.409; p<0.001), relative and absolute values of: fat content (F=21.997, p<0.001, F = 25.777, p<0.001), lean body mass (F = 22.186, p<0.01, F = 8.890, p<0.001), body water content (F = 19.128, p<0.001, F = 5.287, p<0.01), body mass index (F = 33.086; p<0.01). Post hoc analysis showed that the different groups of subjects differed in terms of: body weight (except comparisons I÷III, I÷IV, III÷IV, at p<0.001), relative (except III÷IV) and absolute fat content (except III÷IV), lean body mass content in relative (except III÷IV) and absolute values (except I÷III, I÷IV, II÷IV and III÷IV), as well as relative (except I÷IV and III÷IV) and absolute (except I÷III, I÷IV, II÷IV and III÷IV) body water content and body mass index (except III÷IV) –Table 1.

Anaerobic power of the studied groups

The groups differed significantly in the value of total work performed during the 30-second test (F = 7.1, p<0.001), with post hoc analysis showing

Table 1. Mean values of the somatic indices of the study groups.

Group	Age [years]		BW [kg]		BH [m]		BF [%]		BF [kg]		FFM [%]		FFM [kg]		TBW [%]		TBW [kg]		BMI [kg/m²]	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
I (n = 12)	22.58	6.15	67.78	3.6	180.92	3.40	10.10	2.36	6.90	1.81	89.89	2.36	60.87	2.75	65.82	1.71	44.57	2.02	20.72	0.19
II (n = 12)	26.50	8.60	93.90	14.18	177.58	10.50	21.56	2.87	20.42	4.80	78.42	94.16	73.47	10.37	56.05	73.53	52.95	9.86	29.85	2.01
III (n = 12)	25.92	7.40	73.05	10.01	174.00	7.20	15.60	4.52	11.74	4.58	84.38	4.50	61.31	6.17	61.76	3.29	44.87	4.52	24.14	3.05
IV (n = 12)	22.17	1.27	77.68	7.60	181.75	7.41	14.63	3.77	11.51	3.47	85.36	3.75	66.17	5.67	62.49	2.74	48.44	4.13	23.57	2.54
F	1.422		16.409		2.624		21.997		25.777		22.186		8.890		19.128		5.287		33.086	
p<	NS		**p<0.001**		NS		**p<0.001**		**p<0.001**		**p<0.001**		**p<0.001**		**p<0.001**		**p<0.01**		**p<0.001**	
I÷II	NS		**p<0.001**		NS		**p<0.001**		**p<0.001**		**p<0.001**		**p<0.001**		**p<0.001**		**p<0.01**		**p<0.001**	
I÷III	NS		NS		NS		**p<0.01**		**p<0.05**		**p<0.01**		NS		**p<0.05**		NS		**p<0.01**	
I÷IV	NS		NS		NS		**p<0.05**		**p<0.05**		**p<0.05**		NS		NS		NS		**p<0.05**	
II÷III	NS		**p<0.001**		NS		**p<0.001**		**p<0.001**		**p<0.001**		**p<0.001**		**p<0.001**		**p<0.01**		**p<0.001**	
II÷IV	NS		**p<0.001**		NS		**p<0.001**		**p<0.001**		**p<0.001**		NS		**p<0.001**		NS		**p<0.001**	
III÷IV	NS		NS		NS		NS		NS		NS		NS		NS		NS		NS	

Legend: **Age**, **BW** (body weight), **BH** (body height), **BF** (body fat), FFM (fat free mass), **TBW** (total body water), **BMI** (body mass index). **Group I** athletes, **Group II** power triathletes, **Group III** combat sports, **Group IV** students. **M** mean values, **SD** standard deviation, **NS** not statistically significant.

that power triathletes achieved significantly higher values of this indicator than representatives of combat sports and athletes. Absolute values of maximal anaerobic power were significantly different between the groups (F = 8.288, p<0.001), with the lowest values of this variable recorded in athletes. Post hoc analysis showed significant differences between the athlete and power triathlete groups (p<0.001) and the student athletes (p<0.05). Also, the power triathletes showed a significantly higher value for this variable compared to the combat sports group (p<0.01). Mean power (F = 6.823, p<0.001) and power drop index (F = 2.941, p<0.005) were also significantly different between groups. Post hoc analysis showed that athletes differed significantly for average power in relation to triathletes (p<0.01) and power triathletes in relation to combat sports (p<0.01) – Table 2.

DISCUSSION

When proceeding to interpret the results obtained, it should be borne in mind that athletes in power triathlon, athletic middle and long distance running and combat sports are still actively training athletes who have probably not yet reached their maximum performance. It can be suspected that the peak of adaptive capacity for physical exertion has not yet occurred. The contribution of the energy systems engaged in the individual sports must also be taken into account. Therefore, the exercise capacity of the groups in the anaerobic test differed significantly.

Somatic changes and body composition

Analysis of the somatic characteristics of the study groups showed significant differences in body mass between athletes and power

Table 2. Values of the anaerobic power indices of the groups studied.

Group	W [KJ/30sec]		Pmax [W]		Pmax [W/Kg]		Pmean [W]		Pmean [W/Kg]		Pmin [W]		WSM [W/sec.]		WSM [%]	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	X	SD
I (n=12)	16.71	1.94	852.66	178.34	12.54	2.32	569.78	59.06	8.41	0.74	397.32	68.04	20.83	18.06	53.32	16.82
II (n= 12)	22.27	4.56	1322.33	382.35	13.91	2.72	748.80	154.18	7.92	0.71	436.59	163.58	31.08	12.04	62.22	9.26
III (n=12)	17.34	2.68	917.26	162.44	12.60	1.81	582.88	90.92	7.98	0.46	394.83	69.12	19.60	4.71	56.47	6.61
IV (n=12)	18.92	3.16	1139.50	250.89	14.52	2.50	636.01	105.76	8.11	0.89	397.37	78.68	27.27	7.39	64.68	5.44
F	7.100		8.288		2.069		6.823		1.099		0.444		2.577		2.941	
p<	**p<0.001**		**p<0.001**		NS		**p<0.001**		NS		NS		NS		**p<0.05**	
I÷II	**p<0.001**		**p<0.001**		NS		**p<0.01**		NS		NS		NS		NS	
I÷III	NS		NS		NS		NS		NS		NS		NS		NS	
I÷IV	NS		**p<0.05**		NS		NS		NS		NS		NS		NS	
II÷III	**p<0.01**		**p<0.01**		NS		**p<0.01**		NS		NS		NS		NS	
II÷IV	NS		NS		NS		NS		NS		NS		NS		NS	
III÷IV	NS		NS		NS		NS		NS		NS		NS		NS	

Legend: **W** amount of work performed during 30 s [kJ], **Pmax** maximum power [W], [W/kg b.c.], **Pmean** average power (Pmean) [W], [W/kg b.c.], **Pmin** minimum power (Pmin) [W], **WSM** rate of power loss between maximum and minimum power [W/s], [%]; **Group I** athletes, **Group II** power triathletes, **Group III** combat sports, **Group IV** students. **M** mean values, **SD** standard deviation, **NS** not statistically significant.

triathletes, triathletes and representatives of combat sports, triathletes and the control group. A study by Garrido-Chamorro et al. [27] also showed similar differences between body mass index and body composition of different groups of elite athletes. Similar findings were shown by Grabarczyk et al. [28], identifying the desirable body composition predispositions of athletes for different sports. Research into the importance of somatotype in terms of the ability to train specific aerobic capacity traits suggests that it influences the nature of the training undertaken and its effects [29, 30]. In our study, significant differences in relative and absolute body fat content occurred between all groups, with the exception of the combat sports group and students. Differences also occurred in the content of lean body mass, and the lack of significant values occurred again between combat sports athletes and the control group. Low body fat is an adaptive element of the body, useful in most sports and hence, its relatively low state in competitive athletes should be considered appropriate [31, 32]. Only power triathletes were characterised by an excess of body fat in relation to population norms [33, 34], while athletes had a significantly lower body fat content compared to the other groups. The differences noted are probably related to the need for combat sports and powerlifting athletes to control their body mass due to their specific weight categories. Their training and diet must meet these requirements and, taking into account preparation times, lead to a reduction in weight before competitions and a temporary increase at other times. This may be related to frequent dehydration, which also affects body composition and health [35]. In our study, the participants were in the middle of a preparation period, so their body mass and body composition were not artificially altered, such as in a competition setting. Somatic characteristics are also dependent on the energy processes that occur during the training of specific sports. During endurance exercise, the main sources of ATP resynthesis are carbohydrates and fats. The ratio of their consumption is determined by factors such as exercise intensity, type of training used, training status and diet [36, 37, 15]. During efforts exceeding 50% VO2max, the contribution of fats to ATP resynthesis decreases, while the contribution of carbohydrates, whose availability in muscle is limited, increases [38]. Low body fat was particularly noticeable in runners, and although their energy requirements due to undertaking prolonged endurance exercise are high, they maintain a lean physique for ergonomic reasons.

Anaerobic power

Anaerobic power in men reaches maximum values between 20 and 30 years of age, after which it decreases due to involutionary changes in the nervous system, atrophy of fast-type neuromotor units, and a decrease in elastic properties of muscles [7]. The highest values of work performed in our study were obtained by power triathletes, and a post hoc test showed significant differences between the athletic and power triathlete groups, as well as triathletes and combat sports. This is due to the characteristics of the disciplines they train, where anaerobic power in power triathletes is the most desirable determinant of athletic success [39, 7]. Absolute values of maximum anaerobic power were lowest in runners. The post hoc test showed significant differences between the groups of athletes and triathletes, as well as athletes and students. Representatives of power triathletes also differed significantly from representatives of combat sports. Absolute values of anaerobic power result from obtaining it in a short period of time, differentiating the selected groups according to the values of loads occurring in strength and power training, especially high in power triathlon [15, 40]. Also, the mean power and power drop rate were different between the groups. The results of the post hoc test indicated that athletes differed significantly in the case of average power developed in relation to triathletes, and power triathletes in relation to combat sports. Practising these sports differentiates trainees in terms of their ability to develop power, and high index values are necessary components of sporting success, which is also confirmed by other studies [2, 8].

CONCLUSIONS

In the light of the quoted results of our own research and discussion with the results taken from the literature, it seems reasonable to verify the view that somatic variables, body composition, anaerobic capacity, may be important qualifiers of variation in the changes occurring in the bodies of the athletes studied.

Taking into account the above information, some more specific conclusions can be proposed:

1. Despite non-significant differences in age and body height, the men studied differed significantly in BMI and body composition, which may indicate a causal effect of the different types of training applied to them.

2. Significant differences in the absolute values of work done (W), absolute maximum anaerobic power (Pmax) and average absolute anaerobic power (Pmean) may be due to differences in the body mass of the subjects, but also to the type of training used.

3. Significant intergroup differences in the relative values of the power drop index (WSM) suggest that the training sessions used may have differentiated the study groups in terms of anaerobic power, although the relative values of Pmax and Pmean do not support this observation.

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