ORIGINAL ARTICLE

Differences in the level of anaerobic and aerobic components of physical capacity in judoists at different age

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

Tomasz Pałka[1ABCDE], Grzegorz Lech[2ABCDE], Anna Tyka[3ABDE], Aleksander Tyka[1BDE], Katarzyna Sterkowicz-Przybycień[4BDE], Stanisław Sterkowicz[2BDE], Agata Cebula[1DE], Aleksandra Stawiarska[5DE]

[1]Institute of Biomedical Sciences, Department of Physiology and Biochemistry, University School of Physical Education, Cracow, Poland
[2]Institute of Sport, Department of Sport and Kinesiology, Combat Sport Unit, University School of Physical Education, Cracow, Poland
[3]Department of Recreation and Biological Regeneration, University School of Physical Education, Cracow, Poland
[4]Institute of Sport, Department of Gymnastics, University School of Physical Education, Cracow, Poland
[5]Doctoral Studies, University School of Physical Education in Cracow, Poland

Source of support: Departmental sources

Received: 30 November 2011; **Accepted:** 08 July 2012; **Published online:** 30 August 2013

ICID: 1063994

Abstract

Background & Study Aim: The main aim of this study is answer to the question of which indices of body's physical capacity differentiate professional judo from other athletes at different chronological age and sport experience.

Material & Methods: The study encompassed 25 professional judoists at the age of senior, junior and cadet, numbered among the best athletes in Poland. The study included the measurements of indices of morphological body build, followed by the Wingate test and graded exercise test to exhaustion.

Results: The study results revealed that the groups of judo contestants, varied in terms of chronological age and training experience, did not differ in their maximal aerobic capacity ($\dot{V}O_2max$). The groups of athletes differed significantly in terms of time of exercise over the TDMA threshold. Anaerobic capacity, determined by total work (TW) in the Wingate test, differed across the groups of judoists included in the study. The averaged levels of this index were highest in the senior group while the lowest values were found in the group of cadets. Level of phosphagenic capacity, expressed by the results of peak power (RPP), showed the highest levels in seniors. However, no significant intergroup differences were observed for the level of this index.

Conclusions: 1. Many years of specific judo training contributes more to development of anaerobic than to aerobic functional capacity.

2. Faster initiation of the anaerobic energy transformations and higher amount of work done over the TDMA during graded exercise test in seniors compared to juniors might affect the course of the judo fight.

Key words: judo • $\dot{V}O_2max$ • peak power output • TDMA • body composition

Corresponding address: Tomasz Pałka, Institute of Biomedical Sciences, Department of Physiology and Biochemistry, University School of Physical Education, Al. Jana Pawła II 78, 31-571 Cracow, Poland; e-mail: wfpalka@wp.pl

Judo - a martial art (budo) formulated by Jigoro Kano, based on his development and adaptation of several styles of ju-jitsu as well as his own philosophical ideas.

Cadets – contestants whose calendar age is 15–16 years.

Juniors – contestants whose calendar age is 17–19 years.

Seniors – contestants whose calendar age is 20 years or more.

VO_2max - maximal minute oxygen uptake. VO_2max is expressed as an absolute rate in litres of oxygen per minute ($l \cdot min^{-1}$) or as a relative rate in millilitres of oxygen per kilogram of bodyweight per minute ($ml \cdot kg \cdot min^{-1}$).

Peak power output – maximal power generated by the body during anaerobic test.

Introduction

The sport sciences focus on a wide range of interdisciplinary problems from a number of scientific domains such as theory and physiology of sport, biomechanics, sport psychology, nutrition hygiene and, more recently, genetics of sport. Problems of sport training must be, therefore, considered in a comprehensive manner. They include both the issues of exercise intensity in training macro cycles, necessary rest ratios, different aspects of athletic recovery and the methods of monitoring of functional adaptations in human body using the most reliable information carriers [1, 2]. Some researchers [1] argue that the major difficulty for the coaches who control athletes' training regimes lies in the specific character of the activities which affect functional capacity of human body. The degree of difficulty in coaching athletes rises markedly in athletes who differ in their biological age, since training-induced adaptations are mainly accompanied by morphofunctional responses typical of a particular phase of ontogenesis. The attempts to determine the post-exercise adaptive response in athletes at different age, within the same sport, and at a high skill level seem to be legitimate and innovative.

Depending on the type of the sport practiced, an athlete is required to exhibit high specific efficiency of energy transformation in the body. Elite athletes in endurance sports, for example, show very high efficiency of exercise-related mechanisms of oxygen supply, which is almost twice higher than in untrained subjects and in athletes in the sports based on speed and strength. Maximal oxygen uptake ($\dot{V}O_2max$) in the world-best endurance athletes is even twice higher than in untrained subjects [3, 4]. In contrast, anaerobic capacity, viewed as "a capacity of human body to perform short exercise at very high intensity of speed and strength character" is similar in these athletes compared to those untrained [5]. When coaching children and young people, continuous monitoring of indices of aerobic and anaerobic components of physical capacity has become a necessity today. This is due to the fact that changes in functional capacity can be observed in human body throughout the ontogenesis, resulting from morphological and functional transformations. At different stages of individual development, the level and rate of these changes is different, which must be taken into consideration by the coaches who plan training load for young athletes. In boys, anaerobic capacity, expressed by the level of peak power output relative to body mass (RPP), increases gradually throughout the growth period. In subjects aged 10 to 12 this index is almost twice higher than in those aged 7. The progress in RPP remains steady until 30 years of age, when it starts to gradually reduce by 6% on average every decade [6-9]. The lowest levels of this index are observed in boys before they turn 10 (RPP 6.7 – 7.2 $W \cdot kg^{-1}$) while the highest values can be found for the age range between 25 and 35 years (9.4 – 9.8 $W \cdot kg^{-1}$) [10]. In people at the age of intensive growth, the level of aerobic capacity, expressed by the level of maximal oxygen uptake ($\dot{V}O_2max$) per minute in relative terms, does not change significantly. Global values of $\dot{V}O_2max$ tend to rise along with an increase in the muscle mass, which is the main oxygen consumer in the body during physical work. Progress in the level of $\dot{V}O_2max$ is observed in boys until they turn 15-16, which is followed by a slowdown. The highest increase in this index is observed during the period of growth spurt. The highest increase in this level is observed at the age of peak height velocity (PHV) [6, 9, 11, 12].

Effective fight carried out by judoists depends on a number of factors. The group of physiological determinants includes in particular those which affect the relative peak power output (RPP) and ability to maintain this power over the period of the whole fight at the highest possible level. The studies carried out by the members of our team [13-15] and other researchers [16, 17] found that maintaining high anaerobic capacity during the fight is possible only when a contestant exhibits high level of effectiveness of aerobic processes, which determines the body's restitution rate both during breaks between the fight bouts and between tournament matches [18]. Empirical evidence shows that high level of aerobic capacity ($\dot{V}O_2max$) in judo contestants is conducive not only to adequate and fast post-exercise recovery [13, 18], but, first and foremost, it is a precondition for high level of activity during the second part of the match and during extra-time [13].

With respect to contemporary knowledge of physiological body properties typical of judoists, it was legitimate to collect and compare the level of exercise functional capacity in the best athletes in Poland at different age i.e. cadets ($\bar{x}$ =15.4 years), juniors (17.4 years) and seniors (21.9 years). The major focus was on attempts to find the effect of age and training experience on development of the of aerobic and anaerobic components of physical capacity.

Material and Methods

Our cross-sectional study was carried out during a competitive season among 25 judo contestants at different age (seniors 7, juniors 10, cadets 8), who trained in seven top sports clubs in Poland. The project was approved by the Bioethical Committee at the Regional Medical Chamber (Polish: *Regionalna Izba Lekarska*) in Kraków, Poland (No. 47/KBL/OIL/2010). Study inclusion criteria were based on the chronological age, sport experience, weight divisions (the two lightest and heaviest divisions were not included) and sport skill level (each subject in their division had taken at least fifth place in national judo tournaments). Table 1 compares statistical characteristics of chronological age, training experience and basic parameters of somatic build of study participants.

The examinations of judoists from individual age categories were carried out 1 to 2 weeks after the main competitions during the competitive season. They were carried out in an air-conditioned laboratory room in the Department of Physiology and Biochemistry (Polish: *Zakład Fizjologii i Biochemii*) at the University School of Physical Education in Kraków, Poland. The anthropometric measurements included the measurement of body height, using a Martin's anthropometer (USA) with precision of 1 mm, and body mass (BM), measured with an electronic scale manufactured by Sartorius, type F1505 – DZA (Germany) with precision of 1g. Measurements of both skinfolds (triceps and subscapular) were repeated three times by means of Harpenden calliper and then the intra-observer error was estimated. Typical errors of skinfold measurement [19] were 1.8% for triceps, and 2.0% for subscapular. The both measurements were within proper anthropometric tolerance (5%) recommended for skinfolds measurements [20]. Intraclass correlation coefficients (ICC > 0.95) showed high reliability of repeated skinfolds measurements [21]. Body fat percentage was evaluated using the regression equation [22]. Analysis of body composition was carried out using body composition chart BCC [23], which allows for imaging of BMI, FFMI, FMI and PF% at the same time. Body mass index BMI (BMI in kg·m^{-2}), fat mass FM and fat free mass FFM (BM-FM) were then calculated. Similarly to BMI, fat-free mass index (FFMI) and fat mass index (FMI) were calculated [23].

Furthermore, a BMI classification with normal values for subjects aged 18 or older ranging from 18.50 to 24.99 kg.m^{-2} was used. In the case of juniors under 18 years of age and cadets, a new definition of overweight and obesity in childhood was used, based on pooled international data for body mass index and linked to the widely used adult overweight cut of points of BMI (24.5 in 17-year-olds, 23.9 in 16-year-olds, 23.3 in 15-year-olds) [24]. The critical value in assessment of excessive fat in male subjects was set as PF >20% [20].

The Wingate test was employed for the assessment of anaerobic capacity [5]. The main exercise was preceded by 5-minute warm-up using a bicycle ergometer with individually selected intensity of 50% VO_2max with pedalling rate of 60 rpm and with three 5-second maximal accelerations at 2nd, 4th and 5th minute. Two minutes after the warm-up, participants performed 30-second maximal physical exercise. The objective for a studied person was that they would achieve, as soon as possible, maximal rhythm of pedalling and maintain it as long as possible. External resistance of pedalling was selected individually and amounted to 7.5% of body weight. The pilot study demonstrated that athletes obtained the highest peak power (PP) with this pedalling resistance. The test encompassed measurements of mean power (MP), total work (TW), peak power (PP), fatigue index (FI), time to obtain peak power (TOPP) and time of maintaining peak power (TMPP) [10]. Before anaerobic exercise and three minutes after completion of the test, blood samples were taken from earlobes for enzymatic determination of blood lactate (LA) using a Dr Lange PLUS LP-20 photometer (Germany).

Body composition - the term which refers to fat, muscle, bone and water contents. The more popular classifications are FFM and FM.

Table 1. Chronological age, training experience and basic parameters of somatic build in study participants.

	Seniors (1)			Juniors (2)			Cadets (3)		
	N	$\bar{x} \pm SD$	min-max	N	$\bar{x} \pm SD$	min-max	N	$\bar{x} \pm SD$	min-max
Age (Years)	7	21.9± 0.99	20-24	10	17.4±0.73	16-18	8	15.4±0.55	15-16
Training Experience (Years)	7	12.6±1.76	10-14	10	8.5±1.18	8-11	8	6.0±0.81	4-7
BH (cm)	7	180.2±5.39	171-188	10	180.5±3.70	172-185	8	177.1±6,25	170-186
BM (kg)	7	82.9±6.62	71.0-92.1	10	85.4±10.45	72.1-101.1	8	71.6±7.50	56.4-82.0
FFM (kg)	7	74.1±6.20	65.6-82.5	10	72.3±5.49	64.6-78.9	8	65.3±6.25	52.2-73.0

Maximal oxygen uptake (VO_2max) per minute, which is the main indicator of aerobic capacity, was determined by a direct method. Graded test on bicycle ergometer was preceded with a three-minute warm-up with the intensity of 110 W and pedalling cadence (RPM) of 60 revolutions per minute. After the warm-up, power was gradually increased by 20 W, every 2 minutes. The exercise was continued until the subject was unable to manage the pedalling cadence indicated by the metronome. The tests included the measurements of duration of the exercise (DE), minute ventilation (VE), respiratory quotient (RQ), respiratory rate (FR), tidal volume (TV), oxygen uptake per minute (VO_2) and heart rate (HR). Duration of graded exercise (DE) and VO_2max were used as indices of current and potential endurance capabilities of human body. Before the test and three minutes after completion of the exercise, blood samples were taken from earlobes for determination of blood lactate (La). The graded test was carried out on an ER 900 D – 72475 BIT2 Jaeger cycle ergometer (Germany). A cycle ergometer Monark 834 E (Sweden) was used for the Wingate test. Respiratory gas exchange was analysed online (M202E, Medikro, Finland).

The examinations were performed in the attested laboratory in the Department of Physiology and Biochemistry at the University of Physical Education, Krakow, Poland.

Statistica 6.0 PL software package was used for evaluation of the results [25]. Analysis of variance was based, depending on the distribution and homogeneity of variance, on the F-test or Kruskal-Wallis H test. In order to examine the differences between the means from individual groups, the study used the Tukey's test and the Mann-Whitney U-test, which consists in dividing the level of significance of p=0.05 by the number of comparison [26]. Homogeneity of variance was verified by means of Levene's test. In order to test for normal distribution, the authors used the Shapiro-Wilks W-test [25].

Results

The characteristic features of judoists presented in the BCC chart in Figure 1 are mainly marked within the area between the lines of BMI 20 and 30 kg. m^{-2} (from 19.1 to 30.6 kg.m^2), with the fat percentage ranging from 4.5 and 26.5%. Three senior subjects were classified as overweight. The majority (8/10) of the subjects competing within junior age category were characterized by the BMI greater than normal values, which indicates overweight. The situation was reverse in the cadet group: their profiles (5/8) remained below the BMI criterion value. Although 3 judoists from the senior group and 7 others from junior group had the BMI value

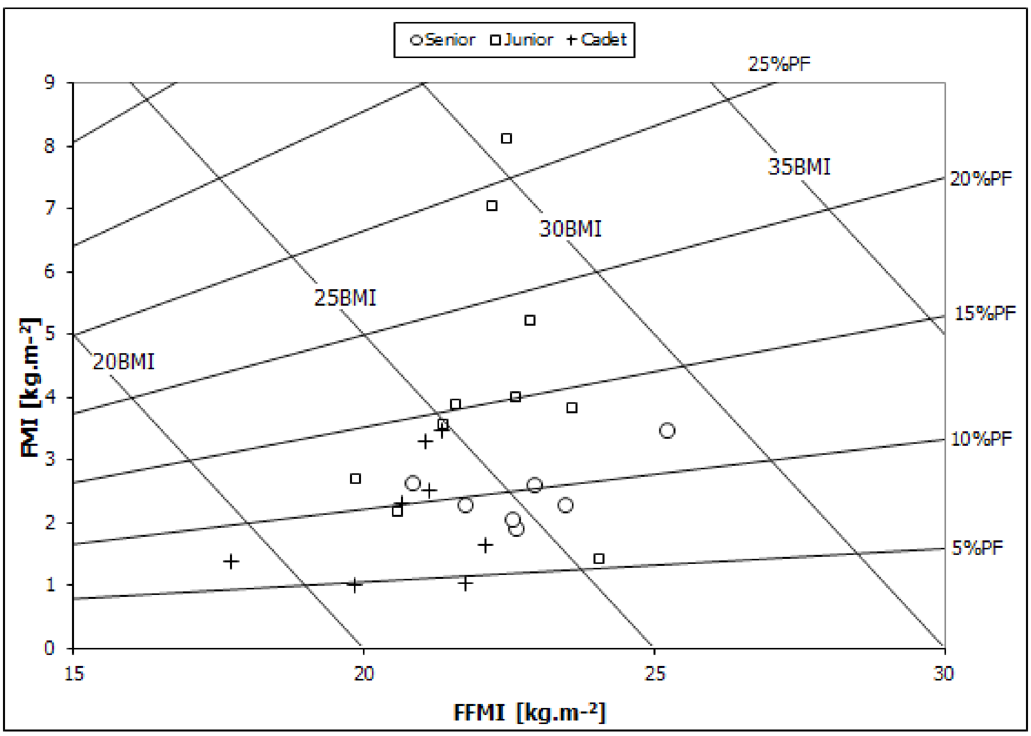

Figure 1. Body composition chart for judoists by age groups. FFMI – fat-free mass index, FMI- fat mass index. Oblique lines represent BMI – body mass index and %PF– fat percentage in body mass.

indicating overweight (and one was obese), the fat percentage cannot be unequivocally accepted as an evaluation criterion because these subjects exhibited a high FFMI levels. Only two junior subjects had PF > 20%. Two judo cadets were very lean (PF<5%). Among all the judoists, who fought at three competitive age levels, the ranges of variation in FFMI and FMI were respectively from 17.7 to 25.2 kg.m^{-2} and from 1.0 to 8.1 kg.m^{-2}. 'Anaerobic capacity, defined by the value of total work (TW) in the Wingate Test, differed over the judoist groups included in the study. Average values of this index were highest in the group of senior judoists (280±10.92kJ) and lowest in the group of cadets (261±10.22kJ). Significant differences in the level of TW were found between the group 1 and 3.

Level of phosphagenic capacity, expressed by the results obtained for peak power (RPP) was highest in senior subjects (12.25±1.00 W·kg^{-1}). However, no significant intergroup changes were found in the level of this index. Post-exercise concentration of blood lactate (La) in seniors was higher (15.64±2.13 mmol·l^{-1}) than in groups of younger athletes, with significant differences found between the group 1 and 3. Variance of the La results (SD ±2.13) for the groups of seniors was higher compared to the group of juniors and cadets (SD ±1.17 and ±1.35 mmol·l^{-1}).

The numerical data contained in Table 3 reveal that the groups of judoists, different in their chronological age and training experience, exhibited similar aerobic capacity ($\dot{V}O_2$max). Average values of this index ranged from 40.60±4.89 ml·kg^{-1}·min^{-1}to 43.52±3.89 ml·kg^{-1}·min^{-1}, respectively in the group 2 and 3. Variance of the results of $\dot{V}O_2$max (SD±2.92 ml·kg^{-1}·min^{-1}) in the group of senior judoists (group 1) was markedly lower than in groups 2 and 3 (±3.89 and ±4.88ml·kg^{-1}·min^{-1}). Significant differences were found in aerobic power (MWL) and the duration of graded exercise (DE). The results of DE and MWL in groups 1 and 2 were higher than in group 3. No differences in maximal heart rate (HRmax) were observed. Post-exercise concentration of blood lactate (La) was significantly higher in group 2 compared to group 3.

Heart rate at the threshold of decompensated metabolic acidosis was lowest in the group of seniors (150±10.67 bpm). Significant differences were found between the groups 1 and 2. Threshold power (WL_{TDMA}) was significantly higher in group 2 compared to group 3, whereas it remained at the threshold of statistical significance between groups 1 and 3. The percentage of maximal oxygen uptake at the TDMA threshold (%$\dot{V}O_2$max) was significantly higher in juniors and cadets than in seniors.

TDMA - threshold of decompensated metabolic acidosis.

The age groups included in the study differed significantly in duration time for the exercise over the TDMA ($\Delta DE = DE - DE_{TDMA}$). Athletes with longest training experience (seniors) exhibited longer time of work over the threshold (697±75.90s) compared to juniors (633±118.70s) and cadets (502±55.00s). Statistically significant differences were found between the groups 1 and 3 and between the groups 2 and 3.

Table 2. Indices of anaerobic capacity

	Seniors (1)		Juniors (2)		Cadets (3)	
	$\bar{x}$ ± SD	min-max	$\bar{x}$ ± SD	min-max	$\bar{x}$ ± SD	min-max
TW (kJ) **	280± 10.92 (3##)	265-298	268±2.98	264-272	261±10.22	247-276
RPP (W·kg^{-1})	12.25±1.00	10.80-13.70	11.27±0.65	10.10-12,11	11.12±0.51	10.38-11.67
FI (%)	42.77±7.51	35.61-56.70	43,37±6.49	32.50-52.40	45.50±5.70	35.65-51.90
TOPP (s)*	4.11±0.61	3.08-4.90	3.49 ± 0.84 (3*)	2.15-4.48	4.63±0.66	3.54-5.37
TMPP(s)	3.20±0.82	2.21-4.22	3.62±0.78	2.52-4.89	3.28±0.85	2.37-4.76
La_{after} (mmol.l^{-1})**	15.64 ± 2.13 (3*)	13.05-18.27	13.54±1.17	11.32-15.19	13.07±1.35	10.81-15.25

*: p<0.05; **: p<0.01.
For multiple comparisons using the Mann-Whitney U-test:
: p<0.016; ## : p<0.01.

Table 3. Physiological indexes measured during the test of graded exercise to exhaustion

	Seniors (1)		Juniors (2)		Cadets (3)	
	$\bar{x}$ ± SD	min-max	$\bar{x}$ ± SD	min-max	$\bar{x}$ ± SD	min-max
$\dot{V}O_2$max (ml.kg^{-1}.min^{-1})	40.80±2.92	37.20-44.90	40.60±4.88	32.22-46.81	43.56±3.89	36.61-49.53
DE** (min)	1213± 162.36 (3##)	1081-1561	1201± 117.57 (3##)	1081-1382	995±119.63	781-1138
HRmax (bpm)	188.0±7.26	175-194	190.60±7.03	181-203	189.11±6.67	176-197
MWL** (W)	297 ± 32.17 (3##)	271-360	295 ± 21.20 (3##)	2769-330	241±18,30	211-270
DE_{TDMA} (s)	524±165.72	360-845	566±60.45	483-660	494±10.11	363-600
HR_{TDMA}** (bpm)	150 ± 10.67 (2##)	135-160	164±6.91	150-173	160±4.58	151-168
WL_{TDMA}* (W)	176.7±26.61	151-230	179.4± 22.33 (3#)	127-210	153.5±16.70	131-170
%HRmax* (%)	80.3± 6.10 (2#)	70.50-88.50	85.9±2.46	84.4-90.7	84.5±1.73	82.4-86.9
%$\dot{V}O_2$max* (%)	65.4± 5,00 (2*, 3*)	59.00-70.00	72.0±6.31	59.36-82.50	71.5±2.54	68.25-76.44
ΔDE (DE-DE_{TDMA}) (s)	697±75.90 (3##)	600-830	633±118.70 (3#)	480-780	502±55.00	420-600
Laafter* (mmol.l^{-1})	11.03±2.07	9.40-15.37	11.87± 1.18 (3#)	10.05-13.21	9.80±1.31	8.43-11.41

*: p<0.05; **: p<0.01.
For multiple comparisons using the Mann-Whitney U-test:
: p<0.016; ## : p<0.01.

Discussion

Although determined genetically, the speed of biological growth and physical capacity of the body might be also the subject to the effect of environmental factors and lifestyles [27]. The major impact on developmental changes is from physical exercise. It is particularly critical not only to the people at younger age but also to the adult athletes. Depending on the nature of a sport and, more specifically, energy support for the exercise, physical training is likely to stimulate the development of particular morphofunctional capacities of human body, which are the basis for formation of specific motor abilities in athletes. An essential role in this case is played by the duration of particular physical stimuli affecting the human body (training experience). As mentioned in the introduction to the present study, attempts to examine the response to physical exercise in young athletes over the course of training-induced adaptations seem to be legitimate [27]. These activities offer opportunities of determination of typical body adaptations in athletes. It is particularly important when considering the methods used and the exercise load, not only for the athletes over the period of dynamic developmental changes, but also for those at the age of junior i.e. after the period of puberty. These observations suggest that training experience in athletes has essential effect on the development of motor abilities and morphofunctional capacities typical of judokas. In the light of these considerations, it was legitimate to compare the level of indices of morphological body build and physiological parameters of anaerobic and aerobic components of physical capacity of judoists in selected age categories: cadets (15.4±0.55 years), juniors (17.4±0.73 years) and seniors (21.9±0.99 years). It should be stressed that the judo fight, which is preceded by specific training, shows an intermittent character; thus, the results of laboratory observations obtained during continuous exercise tests should be considered with utmost caution.

An analysis of the available literature reveals that professional judoists exhibit aerobic capacity ($\dot{V}O_2$max) at the average level (40-45 ml·kg^{-1}·min^{-1}) which is significantly lower than the level found typically in endurance athletes (70-90 ml·kg^{-1}·min^{-1}) [28, 15]. Higher results of maximal oxygen uptake in this sport compared to the study above (45,9 ml·kg^{-1}·min^{-1}) were observed in the representatives of Japan [29]. In another study on Japanese judoists, Muramatsu et al. [30] found that the level of VO_2max was 44.5±7.10 ml·kg^{-1}·min^{-1}. Even higher results of VO_2max were observed in elite athletes from Canada, at different age (cadets/juniors and seniors, respectively 57.62, 59.26 and 53.75 ml·kg^{-1}·min^{-1}) [31]. Similarly to the authors' research, no significant differences in VO_2max were found between the age divisions. In the present study, the levels of this index ranged on average from 40.60 to 43.56ml·kg^{-1}·min^{-1}. This might suggest, with respect to even longer training experience, that many years of using judo-specific physical stimuli did not cause the development of exercise-related mechanisms of oxygen supply in judoists. Furthermore, it was found that, despite the lack of significant differences, seniors had lower VO_2max (40.80 ml·kg^{-1}·min^{-1}) compared to cadets (43.56 ml·kg^{-1}·min^{-1}). The variance of VO_2max results was lower in the group of seniors compared to cadets, which might suggest the effect of selection. With respect to the standards of aerobic capacity proposed by Åstrand [32], the most of the athletes had lower aerobic capacity (39-43 ml·kg^{-1}·min^{-1}) that did not differ from VO_2max results obtained by physically active men who did not practice the sport. It should be noted that the judoists examined by Almansba et al. [33] over the macrocycle encompassing the sub-period of general and special preparation and the competitive season, changes in the level of VO_2max were statistically insignificant, which casts doubt on the legitimacy of the frequent monitoring of this physiological index in adult athletes.

Experiences of the authors of this study suggest that, although the level of aerobic capacity in judoists is not a leading predictor, it plays an essential role with respect to the rate of restitution of the body after the exercise with majority of anaerobic energy transformations [15]. It was found that it determines the effectiveness of the judo fight, with its particular effect in the second part of the match and tournament matches [13]. Lack of significant differences in the level of aerobic capacity of judoists from groups 1 and 2, sometimes evaluated using the duration of graded exercise test, suggests that physical stimuli used in their training have not influenced their aerobic power to a significant degree. Current level of endurance abilities was also determined based on the results obtained for the time to reach the level of TDMA and power obtained at this threshold. No significant differences were found in the groups of seniors (1) and juniors (2), whereas these results in cadets (3) remains at significantly lower level. The worse tolerance of the body to the acidification of the blood in cadets was manifested in considerable lower acidification of the blood after the maximal exercise. The authors were surprised to see the duration of exercise after the achievement of TDMA level (ΔDE) in seniors (group 1) longer than in younger athletes (2 and 3), which, with the lack of differences in the duration of graded exercise (DE) between the groups 1 and 2, suggests that glycolytic anaerobic pathways were initiated faster. This might have significant implications for the practice of sport because faster initiation of anaerobic energy transformations under conditions of judo fight might affect the effectiveness of the offensive or defensive actions. However, the lack of statistically significant differences in blood lactate (La) between the group 1 and 2 after graded exercise points to the improved buffer capacity of the blood and the more effective course of the processes of accumulation and removal of blood lactate during work. In athletes, these body properties are likely to be leading predictors which determine sport skill level. Differences between groups are revealed during comparing of exercise-induced response in seniors and cadets (juniors and cadets) who show lower sport skill level. In sport practice, the Wingate test results are most frequently used to provide information about the current state of anaerobic exercise capabilities of the human body. High level of these indices allows judoists to perform effectively during the fight, when phosphagenic and glycolytic anaerobic pathways play a dominant role. Effectiveness of these processes translates into the amount of work performed at the maximal intensity (TW) and the level of peak power (RPP). These results in seniors (280±10.92kJ and 12.25±1.00 W·kg^{-1}) were higher than in juniors (268±2.98kJ and 11.27±0.65 W·kg^{-1}) and cadets (261±10.22 kJ and 11.12±0.51 W·kg^{-1}). The values of these indices in seniors and juniors did not differ statistically. Similar results were obtained in the study by Mickiewicz et al. [16] carried out among the judoists from judo national team. The results of RPP in seniors (11.2±1.17 W·kg^{-1}) did not deviate from the results obtained for juniors (11.46±1.17 W·kg^{-1}). Convergent results (11.3±0.7 W·kg^{-1}) were obtained by Sterkowicz et al. [34], who examined the athletes who took at least fifth place in national-level junior judo tournaments. In Japanese judokas, significantly higher results for the relative peak power were observed compared to Polish athletes (14.4 ± 0.9 W·kg^{-1}) [30].

A characteristic tendency for juniors to obtain better results in TOPP and TW compared to cadets (the shortest training experience) was observed in the groups of athletes included in the study. Effectiveness of a judoist during the fight is also determined by the time of obtaining greatest possible power. Some researchers [3] argue that the indicator for these properties of an athlete's body in the anaerobic Wingate test is the time of obtaining peak power (TOPP). Its usefulness for the evaluation of what is termed 'competitive speed' in judokas seem to be questionable due to the specific nature of the work performed under the laboratory conditions i.e. pedalling in a bicycle ergometer, which does not require maintaining balance through involvement of body trunk and lower extremities. The level of this index did not differ for the athletes according to their overall experience expressed by age and training experience. The time to obtain peak power was shorter in juniors (3.49 ±0.84s) than in seniors (4.11±0.61s).

The power and capacity of glycolytic anaerobic sources can be determined by the concentration of blood lactate (La) and the amount of the accumulated oxygen deficit. The samples taken from seniors' earlobes three minutes after the Wingate tests [5] exhibited significantly higher blood acidification (La 15.64 $mmol \cdot l^{-1}$) than the samples taken from cadets (La 13.07 $mmol \cdot l^{-1}$). The blood samples taken during fight and directly after it was completed showed that the blood lactate concentration (La) in judo contestants of champion class was on average 11.10±5.31$mmol \cdot l^{-1}$, which points to a dominant contribution of the anaerobic pathways to glycolytic exercise [35], with the individual levels of La concentrations reaching even from 17.6 to 21 $mmol \cdot l^{-1}$[36]. This causes that training of professional athletes necessitates periodical monitoring of bioenergetic indices which allow athletes to control the metabolic response of the body to even individual load within a particular training unit [37]. Body composition of the senior judoists exhibited lowest variability of PF%, which is advantageous in aerobic exercise and might result from training and sport selection.

Authors of this study realize that drawing cause-and-effect conclusions from cross-sectional studies might be risky. The presented results would have to be supported by the evidence from longitudinal studies. At present it is difficult to answer to the question of which of the cadets will be successful when they progress to junior and senior divisions since judo stability of competitive success is not high in any of the age division [38].

Conclusions

1. Many years of specific judo training contributes more to development of anaerobic than aerobic capacity of human body.

2. Faster initiation of the anaerobic energy transformations and higher amount of work done over the TDMA during graded exercise test in seniors compared to juniors might affect the course of the judo fight.

Acknowledgements

Authors of the study would like to thank to technical workers in the Department of Physiology and Biochemistry and Zbigniew Szygula, Ph.D. for medical assistance.

References

1. Bouchard C, Malina RM, Perusse L: Genetic of fitness and physical performance. Champaign(IL): Human Kinetics; 2002
2. Malina RM, Bouchard C: Growth, maturation and physical activity. Champaign(IL): Human Kinetics; 2004; 329-35
3. Tyka A: Wybrane zagadnienia z fizjologii sportu. Med Sport 2004; Vol. 8, Suppl. 1: 5-17 [in Polish]
4. Tyka E, Tyka A, Pałka T et al.: Fizjologiczne i morfologiczne zmiany adaptacyjne organizmu najlepszych polskich snowboardzistów obojga płci w longitudinalnych obserwacjach. In: Krasicki S (ed.), Sporty zimowe strategia rozwoju badania naukowe. Studia i Monografie nr. 31. Kraków, AWF, 2005; 87–98 [in Polish]
5. Bar-Or O: The Wingate anaerobic test: An update on methodology, reliability and validity. Sports Med 1987; 4(6): 381-394
6. Klimek A: Przebudowa czynności ustrojowych limitujących efektywność wysiłku fizycznego dziecka w okresie rozwoju..AWF Poznań: Monografie Nr 196; 1981 [in Polish]
7. Makrides L, Heigenhauser GJ, McCartney N et al.: Maximal short term exercise capacity in healthy subjects aged 15-70 years. ClinSci (Lond) 1985; 69(2): 197-205
8. Inbar, O, Bar-Or O: Anaerobic characteristics in male children and adolescents. Med Sci Sports Exerc 1986; 18(3): 264-269
9. Klimek AT: Dynamika zmian wybranych parametrów układu oddechowego i krążenia w odpowiedzi na wysiłki interwałowe u chłopców przed i popokwitaniowej fazie rozwoju. Praca doktorska, AWF Kraków; 1995 [in Polish]
10. Inbar O, Bar-Or O, Skinner JS: The Wingate Anaerobic Test. Champaign (IL): Human Kinetics; 1996
11. Klimek AT, Cempla J, Pilch W: Exercise-induced changes in pre-and post-pubertal boys:Biol Sport 1998; 15(3):151-156
12. Dencker M, Thorsson O, Karlsson M et al.: Daily physical activity and its relation to aerobic fitness in children aged 8–11 years. Eur J Appl Physiol 2006; 96(5): 587-592
13. Lech G, Tyka A, Pałka T et al.: The physical efficiency and the course of fights and the sports level of judo contestants. Med Sport Practica, 2007; 8: 81–85
14. Lech G, Tyka A, Pałka T et al.: Effect of physical endurance on fighting and the level of sports performance in junior judokas. Arch Budo, 2010; 6: 1–6
15. Pałka T, Lech G, Tyka A et al.: Wydolność fizyczna i morfologiczna budowa ciała profesjonalnych judoków i nietrenujących mężczyzn. Antropomotoryka 2010; 20(50): 85-89 [in Polish, English abstract]

16. Mickiewicz G, Starczewska J, Borkowski L: Fizjologiczna charakterystyka zawodników kadry narodowej judo. Sport Wyczynowy 1988; 9(285): 46-50 [in Polish]
17. Zatoń M: Wartości kryteriów fizjologicznych w kontroli i regulacji treningu sportowego. AWF Wrocław: Studia i Monografie nr 22; 1990 [in Polish]
18. Lech G, Pałka T, Sterkowicz S et al.: Effect of physical capacity on the course of fight and level of sports performance in cadet judokas. Arch Budo, 2010; 6: 123-128
19. Hopkins WG: Client assessment and other new uses of reliability. Part of a mini-symposium presented at the Annual Meeting of the American College of Sports Medicine in Baltimore, May 31, 2001. Available from URL http://www.sportsci.org/resource/stats/precision.html (accessed October 26th, 2010)
20. Raschka C: Sportanthropologie. Leitfaden der modernen, vergleichenden Sportanthropologie, Sportanthropometrie und trainingsrelevanten Konstitutionsbiologie. Köln: Sportverlag Strauss; 2006 [in German]
21. Vincent W. Statistics in kinesiology. 3rd ed. Champain (IL): Human Kinetics; 2005
22. Slaughter MH, Lohman TG, Boileau RA et al.: Skinfold equations for estimation of body fatness in children and youth. Hum Biol 1988; 60(5): 709-23
23. Hattori K, Tatsumi N, Tanaka S: Assessment of body composition by using a new chart method. Am Hum Biol 1997; 9: 573-78
24. Cole TJ, Bellizzi MC, Flegal KM et al.: Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ 2000;320:1240–3
25. Stanisz A: Przystępny kurs statystyki. Kraków: StatSoft Polska; 2001 [in Polish]
26. Wilcox R: New statistical procedures for the social sciences. Modern solutions to basic problem, Lawrence Erlbaum Associates, Hilldale,1987
27. Cempla J: Aspekty rozwojowe w fizjologii wysiłku. Med Sport 2004; Vol.8 Suppl. 1: 19-31 [in Polish]
28. Tyka A, Pałka T, Tyka E, et al.: Wskaźniki biometryczne i strukturalne ciała oraz poziom tlenowej i beztlenowej komponenty wydolności fizycznej najlepszych polskich zawodników w wybranych sportach zimowych. In: Krasicki S (ed.), Sporty zimowe strategia rozwoju badania naukowe. Studia i Monografie nr. 31. Kraków, AWF, 2005; 81–86 [in Polish]
29. Ebine K, Yoneda I, Hase H et al.: Physiological characteristics of Exercise and findings of laboratory test in Japanese elite judo athletes. Medecine du Sport 1991; 65: 73-79
30. Muramatsu S, Horiyasu T, Sato S et al.: The interrelationship between aerobic capacity and peak power during intermittent anaerobic exercise of judo athletes. Bulletin of the Association for the Scientific Studies on Judo, Kodokan, Tokyo, 1994;7: 151-160
31. Little NG: Physical performance attributes of junior and senior women, juvenile, junior, and senior men judokas. J Sports Med Phys Fitness1991; Dec; 31(4):510-20
32. Åstrand P-O, Rodhal K: Textbook of physiology. 3rded. New York: McGraw-Hill; 1986
33. Almansba R, Sterkowicz S, Sterkowicz-Przybycień KL et al.: Maximal oxygen uptake changes during judoist's periodization training. Arch Budo 2010; 6(3): 117-122
34. Sterkowicz S, Lech G, Pałka T et al: Body build and body composition vs. physical capacity in young judo contestants compared to untrained subjects. Biol Sport 2011; 271-277
35. Błach W: Judo, wybrane zagadnienia treningu i walki sportowej. Warszawa: Centralny Ośrodek Sportu; 2005 [in Polish]
36. Sikorski W: Aktualne problemy treningu i walki sportowej w judo, Prace i Materiały Instytutu Sportu. Warszawa: Instytut Sportu; 1985 [in Polish]
37. Volkov RI, Nessen JN, Osipienko AA et al.: Biochimija myszecznoj diejatielnosti. Olimpijskaja Literatura, Kijev, 2000 [in Russian]
38. Julio UF, Takito MY, MazzeiL et al.: Tracking 10-year competitive winning performance of judo athletes across age groups. Perceptual and Motor Skills: 2011; 113(1): 139-149
39. Kawamura T, Daigo T: Kodokan New Japanese-English Dictionary of Judo. Tokyo: The Foundation of Kodokan Judo Institute; 2000

Cite this article as: Pałka T, Lech G, Tyka A et al.: Differences in the level of anaerobic and aerobic components of physical capacity in judoists at different age. Arch Budo, 2013; 3: 195-203