LEVELS OF ANAEROBIC AND AEROBIC CAPACITY INDICES AND RESULTS FOR THE SPECIAL FITNESS TEST IN JUDO COMPETITORS

by

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Background. The aim of this study was to evaluate the fitness level in judoka on the basis of some laboratory physiological tests and Special Judo Fitness Test (SJFT) during their preparatory period.

Methods. The 30-second Wingate Test was used to diagnose anaerobic fitness, while aerobic fitness was evaluated by graded exercise tests on treadmill. The SJFT proposed by Sterkowicz was used to evaluate the current level of special fitness preparation of the judoka.

Participants. The study was carried out on fifteen seniors from the judo section of Wisła-Code Sports Club in Cracow.

Results. The judoka had a high level of anaerobic fitness because their relative total work was 259.53 ± (S.D.)19.40 J/kg, MAP index amounted to 11.36 ± (S.D.)0.86 W/kg, while the mean value of fatigue index was 0.26 ± (S.D.)0.046 W/kg/s. The time of their effort on the treadmill was on average 10 minutes 38 seconds and the distance was 2297 metres. The maximum oxygen intake per minute during their effort on the treadmill amounted on average to 50.1 ± (S.D.)6.48 ml/kg/min. It took 6 minutes and 36 seconds to achieve the threshold running speed-TDMA (v = 3.33 ± (S.D.)0.24 m/s. The Special Judo Fitness Test, which was periodically interrupted to simulate fighting bouts and SJF index, correlated with both the parameters of anaerobic capacity (relative total work, maximum anaerobic power, fatigue index) and with those of aerobic fitness (time and distance covered on the treadmill, relative $V0_2max$, threshold running speed at TDMA, and the time the judoka took to achieve it).

Conclusion. Taking into account the common variance of the results of the Special Judo Fitness test with the parameters gathered during the laboratory physiological tests (32.5 - 71.1%), it was pointed out in the conclusion to this study that the SJFT could be alternatively used to evaluate the effort tolerance in judoka, especially under circumstances where the laboratory facilities are not available for coaches during training.

Keywords: Judo – aerobic – anaerobic – conditioning – fitness evaluation – specific test.

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Introduction

The results of fitness tests provide important information about the predisposition of particular sports competitors for the specific efforts which they are required to perform during training. The reason given hitherto to justify the exclusive use of laboratory methods of testing has been the limited possibility for the application in a variety of sports disciplines, including judo, of a specific test for the estimate of anaerobic fitness, and the diagnosis of effort ability tended to be restricted to ergometric tests (Zdanowicz & Wojczuk, 1984). This mode has been used to determine the parameters characteristic of anaerobic capacity (Franchini et al., 1998; Klimek et al., 1979; Thomas et al., 1989; Zdanowicz & Wojczuk, 1984; Volkov & Shiyan, 1983), and of aerobic capacity (Matsumoto et al., 1978; Klimek et al., 1979; Thomas et al., 1989). The pulsation test performed on a bicycle ergometer at a varying intensity was supposed to simulate the time characteristics in a judo combat (Mickiewicz & Wojcieszak, 1985).

Only in recent years have specific tests been devised which when performed brought about effort reactions similar to those occurring during competitions (Franchini et al., 1998; Lerczak et al, 1996; Sterkowicz, 1995). During the performance of the Special Judo Fitness Test (SJFT), which involves intermittent effort, the following set of research questions emerged concerning the physiological basis of the results observed:

1. What is the level of anaerobic and aerobic effort capacity in Senior judo competitors (over 20 years of age) during the performance of the Special Judo Fitness Test?
2. To what extent is there a correlation between judo competitors' capacity indices and their results for the Special Judo Fitness Test?

The aim of this paper is to assess Senior competitors' level of training (preparation) in the preparatory period preceding a competition, on the grounds of laboratory tests and on the basis of the SJFT.

Material and Method

Fifteen senior team competitors from the judo section of the T.S. Wisla-CODE sports club took part in the comprehensive tests carried out in the Cracow Academy of Physical Education during a special training sub-period.

The tests were performed on 11th April 1998 in agreement with the team's trainer and with the consent of the participants.

Prior to the main part of the observations the competitors' fundamental biometric indices were measured. Table 1 presents the numerical characteristics ($\bar{x}$ ± S.D.) for the judo competitors' age, weight, height, lean body mass and fat mass. Slaughter's equations (1988) were applied to estimate skinfold, fat mass, and lean body mass.

The tests comprised the following: 1. Laboratory tests which gave estimates for a) anaerobic effort ability (10 indices obtained in the Wingate 30-second test for the lower limbs), and b) aerobic effort ability (14 indices obtained from the treadmill). These observations were performed in the Department of the Physiological Principles of Adaptation in the Institute of Human Physiology at the Cracow Academy of Physical Education.

For Point a) each of the competitors performed a 30-second Wingate Test on an 834E Monark bicycle ergometer connected to a computer collecting data for the lower limbs. Each of the test runs was preceded by a 5-minute warm-up at a relative power of about 60% VO_{2max} and a steady pedalling rate, with four consecutive 5-second periods of acceleration to maximum achievement (at 2, 3, 4 and 5 minutes respectively). The warm-ups were performed on a Jaeger ER-900 bicycle ergometer, followed by a 5-minute break for stretching exercises. After this the tested subjects were required to perform the main part of the 30-second test. The testing load applied to each of the participants was selected on an individual basis, and amounted to 7.5% of the particular subject's body weight (Bar-Or, 1987).

With this set of testing apparatus it was possible to register the time for particular revolutions, and after computer data-processing, a print-out was obtained for the component values contributing to anaerobic capacity and reflecting the particular subject's level of velocity characteristics.

For Test b), 90 minutes after the completion of the anaerobic power test, the subjects went on to carry out the test on a mechanical treadmill with a variable belt speed. Treadmill runs were preceded by a 2-minute warm-up during which the belt speed was 2.5 m/s. The test runs lasted up to "rejection point", that is until the time when the tested competitor subjectively felt too tired to continue. A series of respiratory and circulatory parameters was measured during each test run. The following were taken as the aerobic capacity indices determining competitors' endurance features: test-run time on the treadmill; and VO_{2max} level for a one-minute intake of oxygen (in absolute terms, l/min, and in relative terms, ml/kg of body mass).

An additional set of observation which was made for the interpretation of the parameters recorded during the test-runs was the change in lactic acid (lactate) concentration in the blood (LA) before and 3 - 5 minutes after the test. The anaerobic metabolism threshold value was determined on the basis of the usual criteria for respiratory gas kinetics, and the mechanical and circulatory parameters (speed of test-run, heart contraction rate, and time to reach the anaerobic metabolism threshold) were measured at the point when the anaerobic threshold was reached (Wasserman & McIllroy, 1964; Pilis et al., 1996). Aerobic metabolism was assessed using 2002 Medicro ergospiro-test equipment (made in Finland). The heart rate (HR) was registered telemetrically using Polar Vantage NV sports-testing equipment (made in Finland); while lactate levels were determined using a plus LP 20 miniphotometer (by Dr Lange, Germany).

2. The Special Judo Fitness Test designed by Sterkowicz in Department of Combat Sports in the Cracow Academy of Physical Training (Sterkowicz, 1995, 1996) was conducted in the training gym on 15th April 1998, in the following sequence: two *Uke* judoists in the same weight class and of similar height were positioned at a distance of 6 m from each other, while the tested subject, *Tori*, stood in the middle between them. When the command *Hajime* was given, the *Tori* was required to run up to one of the *Ukes* and perform an *Ippon-seoi-nage* throw, followed by the same type of throw on the second *Uke* (Figure 1). This procedure was repeated for 15 s (Series A), after which the *Matte* command was given, followed by a 10-second break. Series B and Series C followed on after a second and third 10-second break. The heart rate was measured after a 1-minute rest which followed immediately on the Series A, B, and C throws. The index for the Special Judo Fitness Test (SJFI) was calculated according to the following equation:

$$SJFI = \frac{HR_{eff} + HR_{1res}}{A+B+C}$$

where HR_{eff} and HR_{1res} are the heart rate immediately following the effort, and one minute after the test respectively, and A + B + C is the total number of throws effected in Series A, B and C. The lower the index the better the result.

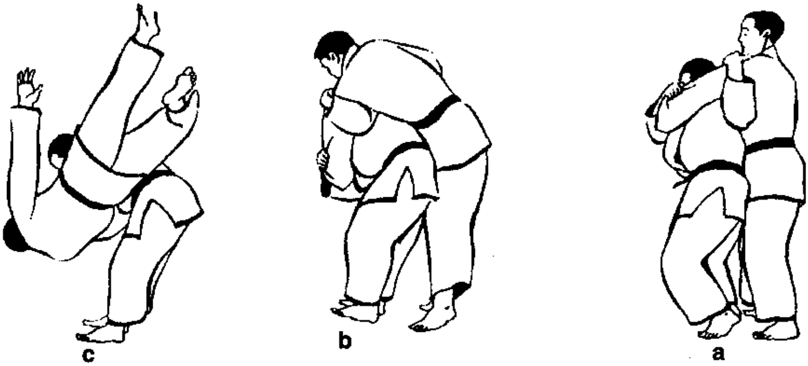

Figure 1. Basic phases of Ippon-seoi-nage throw (after Iwai et al. 1977)

Table 1. General characteristics of judo competitors: age, height, lean body mass, fat mass, percentage fat (n = 15).

	$\bar{x}$	S.D.
Age (in years)	22,8	3,95
Weight (kg)	82,88	16,37
Height (cm)	177,6	9,97
Lean body mass LBM (kg)	70,81	12,22
Fat mass FM (kg)	12,07	4,99
Percentage fat PF (%)	13,72	3,37

The Statgraphics Plus 3.1 computer program was used for the statistical analysis of the data collected. After the results for the respective variables had been checked for normal distribution, their arithmetic means ($\bar{x}$) and standard deviations (S.D.) were calculated, and Pearson's correlation coefficients (r) were computed for the parameters obtained in the laboratory tests and in the Special Judo Fitness Test, which had been designed specifically for judo.

Test results

The test results obtained for physiological effort abilities have been presented in Tables 2 and 3.

Table 2. Judoists' anaerobic capacity indices for 30-second Wingate Test

Indices	$\bar{x}$	S.D.
Mean absolute power (W)	724,53	147,16
Mean relative power (W/kg)	8,75	0,62
Total work TW (kJ)	21,38	3,60
Relative total work (J/kg)	259,53	19,40
Maximum power (W)	941,87	194,23
Relative maximum power (W/kg)	11,36	0,85
Fatique Index (W/kg/s)	0,26	0,043
Time to achieve maximum power (s)	4,04	1,176
Sustenance time of maximum power (s)	3,28	0,797
Lactate concentration (mmol/l)	13,45	1,96

Table 3. Judoists' maximum & threshold physiological indices in treadmill test

Indices	$\bar{x}$	S.D.
Duration of effort tested (s)	637,7	72,40
Maximum running velocity (m/s)	4,83	0,31
Distance covered in run (m)	2297,33	345,99
Maximum oxygen intake VO_{2max} (l/min)	4,27	0,83
Maximum relative oxygen intake VO_2max (ml/kg/min)	50,1	6,48
Maximum heart rate after 1 minute (sys./min)	188,4	8,13
Time to achieve threshold running velocity TDMA (s)	276,0	58,04
Threshold running velocity TDMA (m/s)	3,33	0,24
Heart rate on achieving threshold running velocity HR TDMA	163,3	9,29
Percentage of HRmax on achieving threshold running velocity HR TDMA	87,13	2,69
Percentage of VO_{2max} on achieving threshold running velocity HR TDMA	78,67	5,69
Lactic acid concentration at rest (mmol/l)	2,30	0,31
Lactic acid concentration after effort on treadmill (mmol/l)	13,08	2,21
Difference Δ between LA concentration before and after effort on treadmill	10,77	2,22

The magnitudes for the indices of anaerobic capacities in Table 2 show that the mean power (PW in watts) had a general value of 754.5 ± 147 S.D., which amounted to 8.75 W/kg when expressed as a value per kg body weight.

The total amount of work done in the 30-second test (TW) amounted to 21.38 kJ, with a relative value $\bar{x}$ = 259.5 J/kg.

The magnitude of the peak power (MAP) achieved had a mean total value of 941.87 Watts, and a relative mean of 11.36 W/kg.

The fatique index in the tested group had a mean value of $\bar{x}$ = 0.260 ± 0.04 W/kg/s.

The time needed to generate maximum power (TO MAP) covered a wide range, from 2.76 to 7.41s, with an arithmetic mean of $\bar{x}$ = 4.04 ± 1.176s.

The time for which maximum power could be sustained varied from individual to individual, just like the other parameters, but had a mean value of $\bar{x}$ = 3.28 s.

The lactate levels determined in the samples of arterialized blood drawn in conditions of rest from the players' fingertips were within the standard physiological range, but the 30-second effort test brought about a rise of 10.77 mmol/l.

Generally the results for the Wingate Test were in agreement with the results published by Zdanowicz & Wojczuk in 1984 obtained from similar material for the Polish national team.

Table 3 shows the mechanical and circulatory and respiratory indices recorded during test-runs on the mechanical treadmill.

The time of maximum effort duration had a mean value of 10 min 38 s., though for individual cases it spanned a range from 8 to 12 minutes. The maximum velocity achieved in this time had a mean value of 4.84 x sec^{-1}, and the distance covered was $\bar{x}$ = 2297 m.

The maximum oxygen intake per minute (VO_2) for this group of judoists reached a mean global value of 4.27 l x min^{-1}, which gave a relative value of 50.1 ml x kg^{-1} x min^{-1}.

The threshold for uncompensated metabolic acidosis was reached after a mean time of 4 min 36 sec of effort on the treadmill. The velocity achieved for this was $\bar{x}$ = 3.33 m. x sec^{-1}, and the heart rate after 1minute 163 systoles x min^{-1}. The percentage heart action frequency at the anaerobic metabolic threshold had a mean value of $\bar{x}$ = 78.7% of $VO_{2\,max}$.

Table 4 shows the judoists' achievements in the Special Judo Fitness Test conducted in the same preparatory period as the laboratory tests. They turned out to depend on body composition, and the percentage of fat in the body mass was found to be negatively correlated to results for Series B and C, and the total throws (A + B +C). Fat percentage showed a positive correlation with heart rate after one minute's rest. In consequence, there was a natural correlation observed between fat percentage and the SJFT result.

Table 4. Judoists' results in the Special Judo Fitness Test (n = 15)

SJFT results	$\bar{x}$	S.D.
Series A (15 s)	6,33	0,49
Series B (30 s)	10,80	1,21
Series C (30 s)	10,13	1,25
A+B+C	27,27	2,71
HReff	181,6	6,2
HRres	150,0	11,8
SJF Index	12,29	1,48

Table 5 presents the correlation coefficients for the physiological parameters, which showed a significant correlation with the results achieved in the SJFT.

On the whole judoists who scored higher values for maximum anaerobic power in the Wingate Test had a worse (higher-valued) SJFI ($r = 0.524$; $p < 0.05$), which should be associated with the influence of body mass. When the relative MAP values were considered (in W/kg), this relationship did not appear to be significant. There was a moderate correlation between the MAP/kg index and the number of throws performed in the 15-second Series A of the SJFT (Tab. 5).

Another noteworthy point observed was the relation between the magnitude of relative total work (J/kg) and the cumulative number of throws performed in the SJFT (Fig. 2), and between the fatique index (W/kg/s) and the number of throws performed in Series B of the SJFT (Fig. 3).

Table 5. Correlation coefficients for capacity tests and SJFT results in 15 TS Wisla Senior judoists (Cracow)

	Series A (15 s)	Series B (30 s)	Series C (30 s)	Series A+B+C SJFT	HReff	HR_{1rec}	Index SJFT
Relative total work(J/kg)	0,493	0,700**	0,691**	0,718**	-0,346	-0,105	-0,714**
Max. Power (W/kg)	0,548*	0,310	0,356	0,401	-0,413	0,070	-0,393
Fatique Index (W/kg/s)	-0,099	-0,634*	-0,487	-0,524*	0,005	0,069	0,476
Running time on treadmill(s)	0,286	0,501	0,712*	0,602*	-0,602*	-0,688**	-0,843***
Distance covered in run (m)	0,301	0,501	0,710**	0,601*	-0,607*	-0,687**	-0,842***
Maximum oxygen intake VO_2max (ml/kg/min)	0,106	0,420	0,665**	0,512	-0,468	-0,627*	-0,727**
Time to achieve threshold running velocity TDMA (s)	0,227	0,447	0,581*	0,520*	0,079	-0,338	-0,570*
Threshold running velocity TDMA (m/s)	0,500	0,606*	0,665**	0,666**	0,047	-0,298	-0,671**
Difference Δ between LA concentrations	-0,178	0,052	0,091	0,033	-0,582*	-0,473	-0,260

Note: * - $p < 0,05$;
** - $p < 0,01$;
*** - $p < 0,001$.

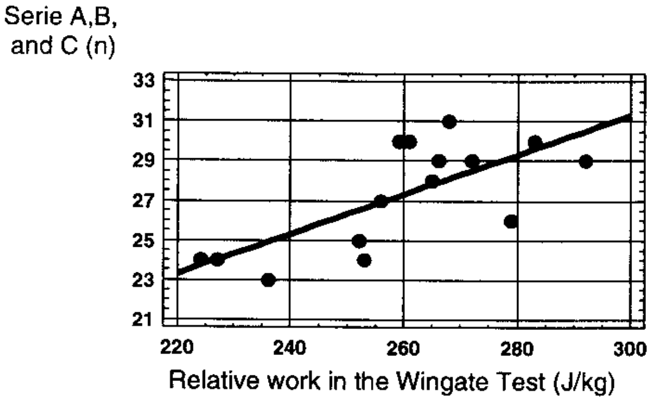

Figure 2. Correlation diagram for relative work in Wingate Test and sum of total number of throws in the Special Judo Fitness Test

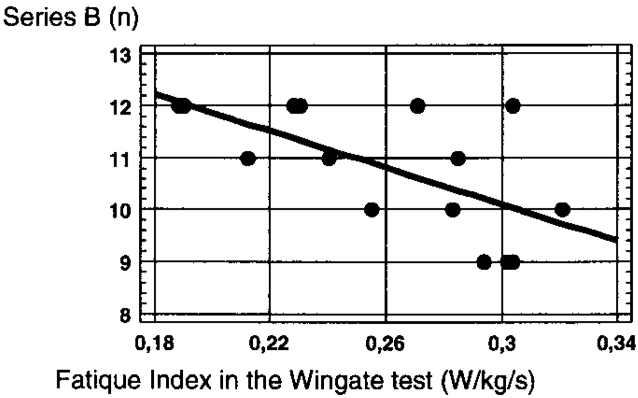

Figure 3. Correlation diagram for fatique index in the Wigate Test and the number of throws in series B of the Special Judo Fitness Test

Moreover there was a correspondence between high values for the relative total work and high numbers of throws in Series C, and also lower (better) SJFI values (Table 5; p.< 0.01).

There was a strong negative correlation between the time spent on the work and the distance covered on the treadmill, and the SJFI (Fig.4). High values for these parameters corresponded to a larger number of throws, especially in Series C, and also to lower heart rates immediately after the effort and after the rest period (cf. Table 5).

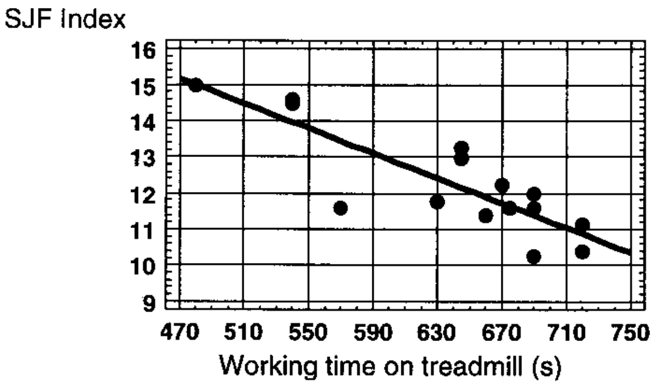

Figure 4. Correlation diagram for time of effort on the treadmill and the SJF Index

Table 5 shows that the time needed to achieve threshold velocity on the treadmill and the TDMA threshold velocity were associated with the number of throws performed in Series C and with the sum total of throws in all three series of the SJFT. A relation was observed between the time for the achievement of threshold velocity (TDMA) and the value of the Special Judo Fitness Index.

The performance of the SJFT might well have brought about high lactate concentrations in the blood, since, as individual HR values showed (Fig. 6), the effort caused an increase in HR above the HR TDMA level. A negative correlation was observed between lactic acid concentration in the blood (expressed as the difference between the values before and after an effort on the treadmill), and the heart rate immediately after the completion of the SJFT.

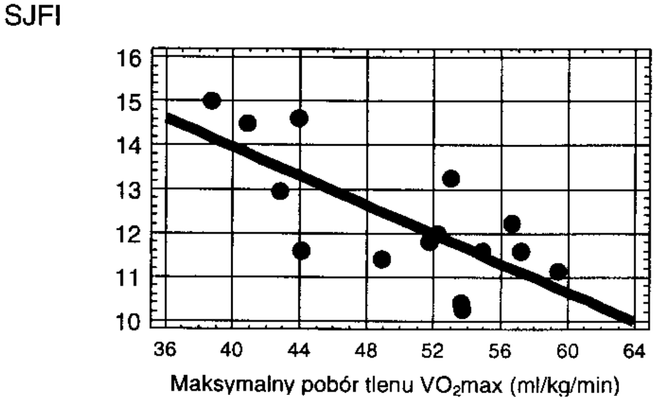

Figure 5. Correlation diagram for maximum oxygen intake and the capacity index in the SJFT (n = 15)

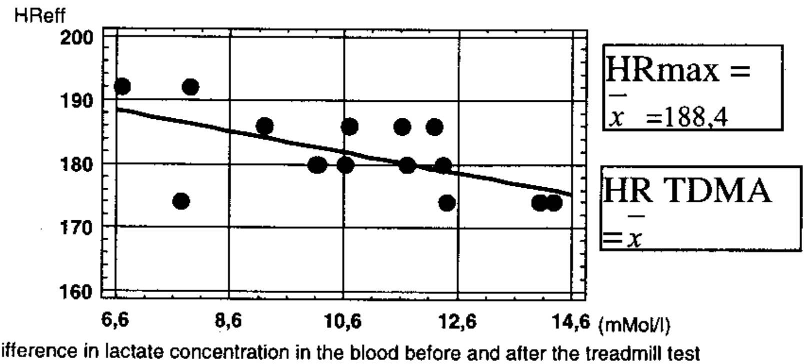

Figure 6. Correlation diagram for the difference in lactate concentrations in the treadmill test and heart rate during effort in the SJFT

a) Judoists' anaerobic effort abilities

Maximum anaerobic power, and especially the mean power per kg body weight (W/kg), may be considered a good indication of judoists' velocity predisposition, which is governed by anaerobic capacity. The Seniors of the T.S. Wisła club had a high MAP level (11.36 W/kg), which was not much worse than the corresponding figure for the Polish national team (11.43 ± 0.91W/kg) (Zdanowicz & Wojczuk, 1984). The mean value reported for the Canadian team was as much as 13.7 ± 1.1 W/kg, while the maximum value was 16.3 W/kg (Thomas et al., 1989).

The relative total work done by the tested TS Wisła judoists was 259.53 J/kg, a slightly higher value than the corresponding mean value for the players in the Polish national team, 257.9 J/kg (Zdanowicz & Wojczuk, 1984). A negative correlation was observed between the percentage proportion of fat in the total body mass and relative total work ($r = 0.60$, $p < 0.05$). In the Wingate Test workload is calculated on the basis of general body mass, so that competitors with a greater fat proportion perform the test under a greater load in relation to lean body mass (Inbar et al., 1996).

The mean time the players in the national team required to achieve maximum power amounted to 2.98 ± 0.98 s. (Zdanowicz & Wojczuk, 1984). One of the T.S. Wisła competitors who had played in the Olympics was 2.76 s., but the arithmetic mean for the whole team was higher, 4.04 s., a worse result.

Physiologists have confirmed that the contribution made by aerobic processes to the 30-second test does not exceed 13%, and that the ability to perform a large work task in such a short time definitely involves an anaerobic energy potential (Wojcieszak et al., 1983). The lactate concentration in the blood, which was on average 13.45 mmol/l for the T.S. Wisla players as compared with 14.5 ± 2.2 mmol/l for the national team (Zdanowicz & Wojczuk, 1984), indicates that during anaerobic effort competitors use up large amounts of their energy substrates.

B) Judo competitors' aerobic capacity

Few of the indices for aerobic capacity determined in the treadmill test may be compared with the data in the literature, since the efforts concerned were made on the bicycle ergometer (Mickiewicz & Wojcieszak, 1985) or in a stadium, where in a 12-minute test Japanese judoists ran a mean distance of 2,878 m. (Matsumoto et al., 1978). The mean velocity during the run was 3.99 m/s for the Japanese competitors, while in our tests the members of T.S. Wisła obtained a lower result on the treadmill (3.6 m/s).

For reasons of methodology further comparisons were restricted exclusively to those results which were recorded for tests carried out on the treadmill. The tested working time for this group of judoists, one of the best teams in Poland, averaged 638 ± 72.40 s; while the corresponding testing time for the Japanese group was 551.4 ± 89.3 s. Also the maximum oxygen intake was similar in the T.S. Wisla (Table 5) and Japanese group (4.06 ± 0.25 l/min - Matsumoto et al., 1978), but less than for the Seniors in the Canadian national team (n = 22, ($\bar{x}$ = 4.49 ± S.D. = 0.57 l/min - Thomas et al., 1989). In relative terms with respect to body weight, the mean value for this parameter was lower for the Polish competitors (50.1 ml/kg/min), while for the Japanese group it was 53.17 ± 3.35 ml/kg/min (Matsumoto et al., 1978), and as much as 59.2 ± 5.18 ml/kg/min for the Canadian national team (Thomas et al., 1989). For a number of national teams the mean value of this index has ranged from 53.2 to 59.2 ml/kg/min (Thomas et al., 1989). In other tests relative values for VO_{2max} for Seniors have been recorded of 53,7 ± (S.D.) 5,6 ml/kg/min, and were significantly lower than for Juniors (59.3 ± S.D. 5.6 ml/kg/min). The higher value for the aerobic index for Juniors may point to a greater contribution made by technical skills to victory for Seniors (Little, 1991). The results of our investigation confirmed the well-known occurrence of a negative correlation between percentage proportion of fat in body mass and VO_{2max} values ($r = -0.86$, $p < 0.01$).

The maximum heart beat rate after 1 minute was slightly lower in the tested Polish judoists than for the Canadian players (191 ± (S. D) 9.6 systoles per min. - Thomas et al., 1989); and significantly lower than the 198.8 ± (S. D.) 6.2 systoles per min reported by Little, 1991. However it should be stressed that both the T.S. Wisla competitors and those tested by Thomas were younger than the Seniors examined by Little (1991), whose age was 25.9 ± 5.3 years.

In the analysis of the parameters on the threshold of uncompensated metabolic acidosis in our tests we showed that the greatest running velocity was 3.5 m/s., while the momentary heart beat rate during the effort was 163.3 systoles/min, that is 87.1% of HR_{max}. The maximum oxygen intake percentage at the moment when the threshold velocity was achieved for running amounted to 78.7% of the relative VO_{2max} index. The threshold values for VO_{2max} were identical for the Canadian Seniors and the Polish Seniors (cf. Little, 1991). Subjected to the same effort during a treadmill test, the top judokas achieved higher threshold velocities, which ranged from 3.00 to 4.00 m/s. lactate concentrations in the blood obtained in the treadmill test were similar to the ones observed after the Wingate Test, with a mean value of 13.8 ± 2.21 mmol/l.

C) Results of the Special Judo Fitness Test and their correlation with the physiological indices for effort ability in Judo Seniors

In the opinion of Klimek and his co-workers (1979), the best proof of physical capacity is the practice of the sport. So the effects of endeavour in this discipline may be assessed on the basis of competitors' maximum metabolic abilities clashing with each other during combats. Their metabolic abilities are determined by the biochemical reactions of their tissues during the performance of work, and on the efficiency of their cardiac and circulatory, respiratory, and nervous and muscular systems (Klimek et al., 1979). We may assume that their anaerobic and aerobic capacities, as well as their rates of restitution during the short intervals between the phases of effort will influence the tactics they use. Individual competitors with high indices for anaerobic capacity will be able to employ an attacking style of combat, while another competitor with high indices for aerobic capacity will be more likely to adopt a defensive style (Thomas et al., 1989). As regards body build, the average parameters for sports competitors differ from those of the general population of individuals who do not practise any sports discipline. This is often accounted for on the grounds of pre-selection or training methods (Heller et al., 1998). Tumilty et al. (1986) stressed that the outcomes of excessive body fatness in judoists may result in their classification in a higher weight category, and a decrease in their relative maximum power index, which reduces their velocity and causes thermo-regulation problems, thereby bringing about a faster rate of fatigue. During training sessions and competitions the muscles of the lower limbs adapt to a mixed (aerobic and anaerobic) work routine (Katsuta et al., 1994). In the heavier weight categories relative VO_{2max} is observed to fall ($r = -0.53$), while the percentage fat proportion in total body weight to increase ($r = 0.64$), along with an increase in the cross-section of Type I and Type IIA muscles ($r = 0.55$ and $r = 0.47$ respectively).

In the individual approach it would be hard to rely only on effort abilities, especially their laboratory estimations only, for definitive conclusions on the performance potential of trained judoists in training sessions and competitions. That is why trainers employ special fitness tests as well, which in a way reflect starting effort.

Although judoists have as many as 99 techniques available, most often the move that determines victory is the *Seoi-nage* throw across the back (Sterkowicz et al., 1997). That is why we chose this throw for Specific Fitness Test proposed by Sterkowicz (1995). In a typical 12-part combat the duration of one sequence of continuous effort ranged from 15 to 35 s., while the interval of intermission lasted from 8 to 17 s. (Svishchov et al., 1990). During combat the working intensity of the heart amounted to 90 - 95% with respect to maximum heart rate (Kaneko et al., 1978). In the SJF test the rate following the completion of Series C was 96.4% of HRmax. It may be readily observed that the durations of the efforts both in the Wingate Test and in the SJFTs are to a large extent analogous to the time structures in combat. Additional tests carried out on the competitors confirmed a high level of similarity between the lactate concentration after the effort in the SJFT and after combat (Franchini et al., 1998).

On the basis of the development processes in human metabolic energies (show diagrammatically in Fig.7), we may classify the types of work performed by sports competitors. In the initial phase of the effort the competitor is fully fit to apply the highly effective mechanism of ATP re-synthesis supplied by the breakdown of phosphocreatin, which provides energy in the form of ATP at maximum intensity for the first few seconds of combat. In the fifth to seventh second of maximum-intensity efforts one of the critical moments occurs, brining a change in the ATP renewal mechanism to anaerobic glycolysis. This point is featured by a drop in power, and hence by a lowering of effort intensity. The second characteristic moment, which comes between the 40^{th} and 50^{th} second of effort, is the increase in the contribution from the aerobic energy potential to ATP production. The consequence of this is a further fall in power and in the competitor's effort ability. The correlation that is observed between the parameters of the Wingate Test, the SJFT, and the treadmill test may be partially explained on the grounds of the energy foundation of efforts lasting for various lengths of time.

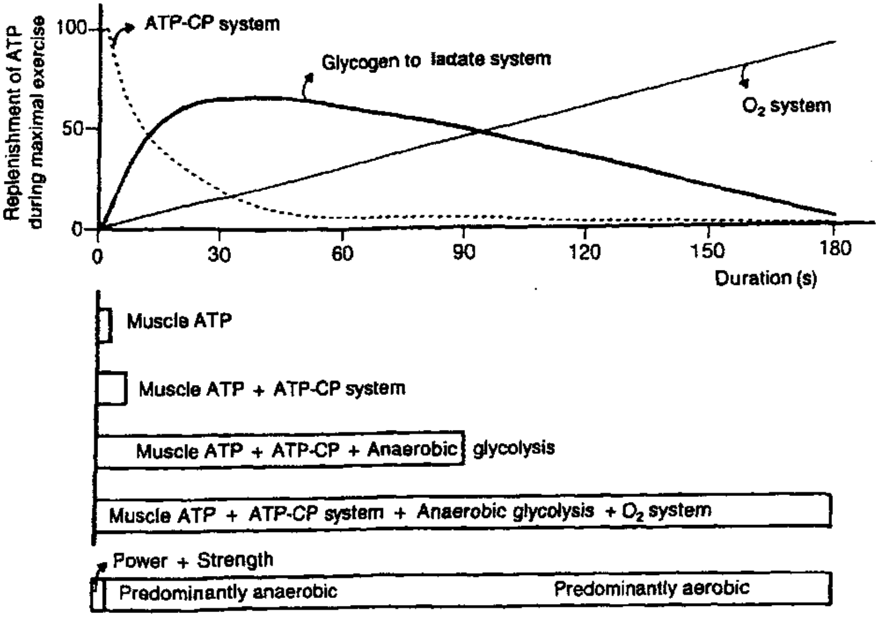

Figure 7. Contribution of anaerobic and aerobic paths of ATP re-synthesis to the overall energy balance for exercises of varying durations (after Malina & Bouchard, 1991)

In the SJFT the time in which Series A was performed amounted to 15 s., which would indicate that it should be recognised as an intensive effort partly based on anaerobic, mostly non-lactic-acid mechanisms of energy transformation in the working muscles. In actual fact there was a moderate correlation between the results for Series A and the relative maximum power (cf. Tab. 5), while the coefficient of determination r^2 explained 30% of the mutual variability.

The short break preceding Series B (10 s.) stimulated aerobic rest processes, but it was certainly not enough for restitution. Nevertheless there was a significant negative relationship between the index for maximum oxygen intake (ml/kg/min) and the heart rate in the first minute of rest.

In Series B of the SJFT the relation between the number of throws and maximum power was significantly attenuated, while the number of B throws and total work (J/kg) in the Wingate Test remained significantly correlated ($r^2 = 0.49$). Moreover the effectiveness of Series B had a 40% mutual variance with the fatique index in power. In outcome of the continuing effort there was also a significant relation observed between the results for Series B and the threshold for running velocity ($r^2 = 0.37$).

In Series C the dependence continued to be observed of the number of throws and the total work performed in the Wingate Test ($r^2 = 0.48$), with a simultaneous intensification of the relation between the number of throws and the threshold running velocity ($r^2 = 0.44$). There were also strong links observed between the data for the last series in the SJFT and the oxygen capacity parameters - working time on the treadmill, distance covered in the run (their r^2 coefficients were respectively 0.51 and 0.50), and the index for maximum oxygen intake ($r^2 = 0.44$). The effectiveness of Series C in the SJFT and the time to achieve threshold velocity had a 34% mutual variance. The strength of these relations increased in the throws of successive A, B, and C Series.

In outcome the overall total number of throws in the SJFT, which simulates a combat episode, was dependent both on the anaerobic capacity parameters (the complete work index and the fatique index), and on the aerobic parameters (working time on the treadmill, running distance covered, time to reach threshold running velocity (TDMA), and its absolute magnitude). Moreover the synthetic SJF index was highly correlated with the index for relative total work in the Wingate Test, the working time, and distance covered, and VO_{2max} (ml/kg/min) in the graded test. This index also showed a significant dependence on the time to achieve threshold velocity and on the TDMA itself. In an earlier set of tests in which the SJFT was carried out on 20 Seniors of the TS Wisla club 4 days before the Polish individual championships, a significant correlation was confirmed between the observed values of this index and the tested subjects' eventual place in the tournament results (Rsp = 0.64; $p < 0.01$) (Sterkowicz, 1996). Mickiewicz (1987) showed that there was a correlation between judoists' maximum anaerobic power and the rank they achieve. A search for relationships between the physiological indices obtained in non-specific tests and competitors' effectiveness revealed that the results of the PWC_{170} test were highly correlated with their attack effectiveness in judo combats (Volkov & Shiyan, 1983).These detected relationships provide information on the competitor's capacity as determined by standard laboratory tests, but the conditions in which such data are obtained are not very similar to what happens during a typical training session or competition, and consequently there is an intrinsic obstacle to the application of these laboratory results to the practice of the sport (Heller et al., 1998).

In the tested group of judoists there was a negative correlation observed between the lactate concentration in the blood (the difference between the values before and after an effort on the treadmill), and heart rate immediately following the SJFT. This dependence is still subject to discussion; it may well be spurious, or perhaps the common factor is tolerance of fatigue and a better movement economy during the SJFT.

Grounds to corroborate such an interpretation of the phenomenon are provided by the strong correlation of the SJFI and the total work index in the Wingate Test ($r^2 = 0.51$), the working time, and the distance covered in the treadmill test ($r^2 = 0.71$), the maximum oxygen intake ($r^2 = 0.53$), and the threshold running velocity ($r^2 = 0.45$). The correlation between the Special Judo Fitness Index and the aerobic variables comes from the fact that the component from the one-minute rest period is taken into account. The drop in heart rate after an effort is a variable which is used quite frequently in estimates of the degree of training.

In conclusion we may state that the Special Judo Fitness test provides important information on competitors' ability to exert effort. It should therefore become one of the basic instruments used to monitor the training progress of highly qualified competitors. The Special Judo Fitness Index an individual judoist scores may serve as one of the criteria in the selection of the intensity of his individual exercises, in line with the recipe that the lower the SJF Index, the greater the competitor's effort capacity.

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