Biology of Sport, Vol. 22 N°4, 2005

PHYSICAL FITNESS AND ANTHROPOMETRICAL DIFFERENCES BETWEEN ELITE AND NON-ELITE JUDO PLAYERS

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Abstract. The objective of this study was to verify the differences between Elite (Brazilian National and International medallists) and Non-elite (nonmedallists in Brazilian National Tournaments) junior and senior judo players. For this purpose, the following tests and measurements were conducted: (a) skinfold thickness; (b) circumferences; (c) breadths; (d) upper body Wingate test; (e) Special Judo Fitness Test; (f) aerobic power and capacity; (h) Lactate after combat during active recovery (70% of velocity of anaerobic threshold) and passive recovery (rest); (i) Isometric hand grip strength. The groups were compared by means of an ANCOVA (covariates – age and weight) followed by a post-hoc Scheffé test (significance level=5%). Elite group presented better results than Non-elite group in the following variables ($p<0.05$): circumferences (cm) - flexed arm, forearm, wrist and calf; breadths (cm) – femur and humerus; Wingate Test – Mean and Peak power; Special Judo Fitness Test – number of throws and index. The other variables were not different between groups. It can be concluded that Elite judo players presented higher upper body and specific anaerobic power and capacity, higher circumferences (specially from upper body, indicating superior muscle mass in this area) and that skinfold, hand grip strength and aerobic power and capacity were similar in Elite and Non-elite judo players. Thus, these results suggest that training and talent identification of judo athletes should focus on the variables that were different between Elite and Non-elite athletes.

(Biol.Sport 22:315-328, 2005)

Key words: Combat sport – Aerobic – Anaerobic - Body composition

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Introduction

Judo is an Olympic sport, which requires technique, tactics and a high level of physical fitness [19]. Some physical fitness and anthropometrical variables are considered requisites for high performance in judo competition [23,26]. Some authors suggested that high-level judo players should have low body fat and high arm circumference [8]. However, body composition differs between weight categories, with higher body fat percentage in half-heavyweight (90 to 100 kg) and heavyweight (more than 100 kg) categories compared with lower categories [26]. Callister *et al.* [6] reported that high level judo players presented lower percent body fat (5.1±0.6 %) compared with judo players qualified worse in USA ranking.

From the physiological point of view, anaerobic power and capacity, strength and aerobic capacity have been pointed as the main characteristics to be developed by judo players [26]. These variables also are different according to weight categories.

The evaluation of judo athletes is difficult because there are few specific tests and the laboratories tests do not simulate the match movements. Indeed, judo players have been evaluated in non-specific tasks. Furthermore, little is known about the differences between elite (E) and non-elite (NE) judo players. Thus, the objective of this study was to verify the differences between E (Brazilian National and International medallists) and NE (nonmedallists in Brazilian National Tournaments) junior and senior judo players in generic and specific tests.

Materials and Methods

Table 1 presents the variables and the number of E and NE athletes evaluated.

The different number of athletes evaluated in each variable is due to the resignation of some judo players in these tasks, mainly because of lack of time to undergo to all the tests and measurements. Both written and verbal informed consents were obtained from subjects prior to their voluntary participation in each part of the measurement and performance assessment program. To minimize fatigue effects, the subjects were tested in six different days during 2 weeks (day 1: anthropometrical measurements and isometric strength; day 2: treadmill test – aerobic power - and upper body Wingate test; day 3: special judo fitness test; day 4: aerobic capacity; day 5: lactate after combat; day 6: lactate after combat). The tests were conducted during 1999 and 2000 in the competitive periods.

Table 1
Variables and number of athletes evaluated

Test/ measurement	Variables	Elite	Non-elite
Skinfold (mm)	Triceps, subscapular, abdominal, suprailiac, front thigh and medial calf	43	93
Circumference (cm)	relaxed and flexed arm, forearm, wrist, chest, proximal thigh, medial calf and ankle	43	93
Breadth (cm)	biacromial, chest, chest depth, biiliac, humerus and femur epicondyles	43	93
Upper body Wingate test (WT)	Mean power (MP in W/kg); Peak power (PP in W/kg); time to reach PP (TPP in seconds) and fatigue index (FI in %)	34	56
Special Judo Fitness Test (SJFT)	Number of throws, heart rate after (beats/min), heart rate 1 min after (beats/min) and index (I=finalHR+HR1min after/number of throws)	23	53
Aerobic Power	VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$) in a treadmill test	15	31
Aerobic Capacity	Velocity of anaerobic threshold (VAT in $km \cdot h^{-1}$) in a treadmill test	16	40
Lactate (LA) after combat	LA ($mmol \cdot L^{-1}$) – 1, 3, 5, 10 and 15 min after a combat simulation (5 min) during active recovery (AR–70% VAT) and passive recovery (PR–rest)	15	31
Isometric strength	Hand grip (HG in kgf) – right and left	26	66

Anthropometrical measurements: – After weight and height, skinfolds thicknesses were measured at least three times per site with a Harpenden caliper. Breadth and circumference measurements were taken at sites defined by Drinkwater and Ross [9]. An experienced evaluator took all anthropometrical measurements.

Upper body Wingate test: – This test was performed on a Monark cycle ergometer adapted for upper body (load of 0.05 $kg \cdot kg^{-1}$ of body mass). Power was measured at each second by the Wingate Test software, which allowed to calculate the following variables – mean power (average power during 30 s), peak power (highest power during the test), time to reach peak power and fatigue index (percent power decrease during 30 s).

Special judo fitness test: the test was performed in three series of 15, 30 and 30 s with 10 s intervals between them. During those series, the athlete executed the ippon-seoi-nage techniques on each of the other two judoists (6 m apart from each other) as many times as possible. Heart rate was recorded immediately after the test and 1 min later. Out of the total number of accomplished throws, the performance index (I) was calculated,

I=HR after+HR 1 min after/NT

where, HR after and HR 1 min after were heart rates immediately and 1 min after the test, respectively, and NT was the total number of throws [10,24]. The smaller the index, the better the test performance. Heart rate was recorded by using a Sport-tester (Polar Electro OY, Finland). This test reliability is r=0.97 [24].

Aerobic power: The initial speed was 6.0 $km.h^{-1}$ with incremental load of 1.2 $km \cdot h^{-1}$ each 1-min. This procedure was continued until the subject's exhaustion. During the entire test the subject was monitored by an electrocardiogram and a heart rate monitor Polar™ Vantage NV (Polar Electro Oy, Finland). The analyses of gases were made with the K4 b^2 instrument (Cosmed, Italy).

Aerobic capacity: It was utilized the Heck *et al.* [14] protocol, which is a progressive treadmill test. The initial speed was 6.0 $km \cdot h^{-1}$ with incremental load of 1.2 $km \cdot h^{-1}$ each 3-min with an interval of 30-s between the stages. At the end of each stage, blood samples were collected from the earlobe for lactate concentration analyses. This procedure was continued until the subject presented two values of blood lactate higher than 3.5 $mmol \cdot l^{-1}$. The AT was the velocity that corresponded to the 3.5 $mmol \cdot l^{-1}$.

Lactate after combat: The combat duration was fixed at 5-min. Each athlete's opponent was the same in the two combats; there was no difference in the body weight between them higher than 10%. This procedure showed a high reliability in the blood lactate concentration after the match (intraclass correlation coefficient=0.92; $p<0.05$). During the passive recovery, the subject remained seated at the tatami during 15-min with the heart rate monitor Polar™ Vantage NV (Polar Electro Oy, Finland). Blood samples were collected before and in the 1st, 3rd, 5th, 10th, 15th min after the combat. During the active recovery, the athlete ran (15-min) at the velocity corresponding to 70% of the Anaerobic Threshold Velocity (VAT). The control of the running velocity was made by marks positioned at each 20-m and a sonorous signal. In the first minute after the match, the subject wore tennis shoes and the heart rate monitor (Polar™ Vantage NV - Polar Electro Oy, Finland). After the blood sample collection, the athlete started his running trial (active recovery). At the 3rd, 5th, 10th and 15th min after the end of the match, blood samples were gotten with brief interruptions of the run. The type of recovery was determined at random.

Isometric strength: static grip strength was assessed, in sequence, for right and left hand using a Takey Kogi (Japan) dynamometer.

Blood lactate analysis: All blood samples were from the earlobe and analyzed on a Yellow Springs Sport 1500 (Yellow Springs Instruments, USA). Previously, the vasodilator pomade Filnalgon TM was applied on the earlobe.

Data analysis: The groups were compared by means of a one-way ANCOVA (covariates – age and weight) for skinfolds, breadth, circumference, SJFT variables, Wingate test performance, isometric strength, VO_2max and velocity of anaerobic threshold. For age, weight and height, the groups were compared with the use of an one-way ANOVA. For blood lactate after fight (1 to 15 min), comparisons were made with a three way (competitive level, time of measurement and type of recovery) ANCOVA (covariate – peak lactate). When differences were found, comparisons were made with a post-hoc Scheffé test. The significance level established was at 5%.

Effect size was calculated as follow:
Effect size: (average E – average NE) / Standard deviation for both groups pooled [32]. Data are presented as mean ± standard deviation.

Results

The groups did not differ (p>0.05) in age (E=22.8±3.4 years old; NE=19.2±4.5 years old), weight (E=81.6±18.7 kg; NE=70.4±14.7 years old) or height (E=177.2±9.9 cm; NE=172.3±8.0 cm).

Table 2 presents the skinfold thickness of both groups.

Table 2
Skinfold thickness (mm) of elite and non-elite judo athletes

Site	Elite	Non-elite
Triceps (mm)	8.4±4.5	8.5±3.7
Subscapular (mm)	13.2±8.9	12.5±7.6
Suprailiac (mm)	9.2±6.8	9.6±6.2
Abdominal (mm)	15.8±11.5	15.4±10.7
Front thigh (mm)	13.7±7.6	14.5±7.5
Medial calf (mm)	8.8±7.3	8.5±4.2

There was no difference (p>0.05) between the groups in any skinfold measure.
Table 3 presents the circumference measurement of the elite and non-elite judo athletes.

Table 3
Circumferences (cm) of elite and non-elite judo athletes

Site	Elite	Non-elite
Relaxed arm (cm)	32.4±3.0	29.6± 3.7
Flexed arm (cm) ***	35.8±3.6	32.1±3.7
Forearm (cm) ***	29.3±3.7	26.5±3.0
Wrist (cm) ***	17.8±1.1	16.8±1.1
Chest (cm)	93.8±8.6	87.8±8.4
Proximal thigh (cm)	59.2±6.4	55.1±5.7
Medial calf (cm) ***	38.9±4.2	36.1±3.9
Ankle (cm)	23.9±2.3	23.6±2.0

***Significant difference between groups (p<0.001)

The elite athletes presented higher flexed arm (effect size=0.90), forearm (effect size=0.80), wrist (effect size=0.83) and medial calf (effect size=0.67) circumferences.
Table 4 presents breadths of both groups of athletes.

Table 4
Breadths (cm) of elite and non-elite judo athletes

Site	Elite	Non-elite
Biacromial (cm)	41±3	39±3
Chest (cm)	29±2	27±3
Chest depth (cm)	20±3	19±3
Biiliac (cm)	28±2	27±2
Humerus epicondyles (cm) ***	10.1±0.8	9.6±0.6
Femur epicondyles (cm) ***	7.3±0.6	6.9±0.5

***Significant difference between groups (p<0.001)

For breadths, the elite judo athletes presented higher values for humerus (effect size=0.67) and femur epicondyles (effect size=0.71) compared to the non-elite judo athletes.

The groups presented similar ($p>0.05$) handgrip isometric strength: Elite – right handgrip=51±10 kgf; left hand grip=49±10 kgf; Non-elite - right handgrip=42±11 kgf; left hand grip=40±10 kgf.

Table 5 presents the upper body Wingate test for both groups.

Table 5
Upper body Wingate test performance for elite and non-elite judo athletes

Variable	Elite	Non-elite
Mean Power ($W.kg^{-1}$) *	5.73±0.77	5.36±0.75
Peak Power ($W.kg^{-1}$) *	7.63±0.98	7.00±1.30
Time to Peak Power (s)	6±2	6±2
Fatigue Index (%)	47.6±8.3	44.9±10.9

*Significant difference between groups ($p<0.05$)

The elite group presented higher relative mean power (effect size=0.47) and relative peak power (effect size=0.52) than non-elite group. Fatigue index and time to reach peak power did not differ ($p>0.05$) between the groups.

Table 6 presents the variables of the Special Judo Fitness Test for both groups.

Table 6
Variables of the Special Judo Fitness Test for elite and non-elite judo athletes

Variable	Elite	Non-elite
Total throws (numbers) ***	28±2	25±2
Heart rate after (bpm)	181±10	186±11
Heart rate 1 min after (bpm)	162±12	165±13
Index ***	12.53±1.11	14.16±1.52

***Significant difference between groups ($p<0.001$)

The elite group performed more number of throws (effect size=1.25) and had a lower index (effect size=1.03) than non-elite group.

VO_2max and VAT did not differ ($p>0.05$) between the groups: Elite – $VO_2max=58.13\pm10.83$ $ml\cdot kg^{-1}\cdot min^{-1}$; $VAT=10.82\pm1.52$ $km\cdot h^{-1}$; Non-elite - $VO_2max=63.28\pm10.55$ $ml\cdot kg^{-1}\cdot min^{-1}$; $VAT=10.80\pm1.67$ $km\cdot h^{-1}$.

Table 7 presents blood lactate after a fight during active or passive recovery.

Table 7
Blood lactate concentration ($mmol\cdot l^{-1}$) after fight during active (AR) or passive recovery (PR)

(LA) ($mmol\cdot l^{-1}$) and moment	Elite		Non-elite	
	AR	PR	AR	PR
(LA) Before	1.78±0.51	1.63±0.66	1.80±0.96	1.96± 0.75
(LA) 1 min	9.85±2.28	9.82±2.07	10.94±3.04	11.17±2.84
(LA) 3 min	9.22±2.40	9.52±1.91	10.10±2.38	10.85±2.92
(LA) 5 min	8.40±2.53	8.67±2.13	9.39±3.32	10.30±2.88
(LA) 10 min	6.21±1.90	7.44±2.16	6.92±2.65	8.81±2.93
(LA)15 min	4.02±1.32	5.59±1.96	4.62±1.92	6.99±2.29
(LA) Peak[a]	10.22±2.11	10.01±1.90	11.22±3.03	11.65±2.87

(LA)-blood lactate concentration; AR-active recovery (70% of velocity of anaerobic threshold); PR-passive recovery; a-highest value attained during the recovery period

Rest and peak blood lactate did not differ ($p>0.05$) between both groups. There was no main effect ($p>0.05$) of competitive level on blood lactate removal. However, there was an effect in the type of recovery ($p<0.001$) and of time of measurement ($p<0.001$), as well as an interaction between time of measurement and type of recovery ($p<0.001$). After 5 min, blood lactate was lower ($p<0.05$) in active recovery compared to passive recovery. Furthermore, blood lactate at 10 min of active recovery was lower ($p=0.000$) than blood lactate at 15 min of passive recovery.

Discussion

Despite no difference between the groups in skinfold thickness, it is important to note that the values were very low for both groups, indicating that those judo athletes were very lean. This result supports the assumption that judo athletes try to maximize lean body mass and minimize fat mass for a given weight category

[5,6,19,26]. A comparison between weight categories was not drawn for this study. Many others studies [7,8,26] compared weight categories concerning the percentage of body fat and they found a linear increase from under 60-kg to 81-90-kg category and a big increase in the body fat percentage in half-heavyweight (90-100-kg) and heavyweight (more than 100-kg) categories compared to lower categories. The only study found, which compared elite and non-elite judo athletes concerning body fat percentage, was conducted by Callister *et al.* [6]. In that study, Callister *et al.* [6] found a lower body fat percentage in better-ranked judo athletes compared with worse ranked judo athletes, which we did not observe in our study. However, in the study by Callister *et al.*[6], it was not reported whether the athletes whom they had compared were of the same weight category, which may suggest that the comparison could have been done between athletes of different categories, which was reported to be different. Another possibility to explain this discordance could be that Callister *et al.* [6] compared the very best athletes in the ranking, while we compared a wider variation of athletes in the present study.

As the athletes in our study were from different weight categories, it was not possible to apply a single equation to determine body fat percentage. In this way, it was assumed that skinfold thickness would be a good indication of body fat.

The higher circumference in arm segments (flexed arm, forearm and wrist) for the elite athletes compared with non-elite judo athletes seems to be in keeping with the assumption that the high arm circumference is an advantageous factor in judo fight. The circumference of a body segment was used as an indication of muscle mass cross sectional area [31]. Recently, more sophisticated techniques have been used [17]. However, the cost of this kind of evaluation is not practical for an evaluation of a big number of athletes. In this way, we can consider that the higher arm circumference of the elite judo athletes can be indicative of higher muscle mass cross-sectional area and consequently of higher power and force output for these segments. The higher calf circumference in elite athletes compared to non-elite athletes can help them in the biomechanics of many throws in which the final movement involves an ankle extension (e.g. seoi-nage) [21]. However, it is important to remind that the effect size for the differences in circumferences were moderate (0.67 to 0.90).

The higher breadth of femur and humerus epicondyles for the elite athletes compared to non-elite, indicate that those athletes have a better bone adaptation to the judo training, which involves many movements such as carrying and pulling the adversary, or a better bone structure that allows them to withstand the training stress. No study has been found on the breadth differences in elite and non-elite judo players. However, a higher bone mineral density determined from dual-energy x-ray absorptiometry was found in judo athletes compared to control subjects. They also presented higher arm bone mineral density compared to other water polo and karate athletes [2].

The isometric strength did not differ between the elite and non-elite judo players, which seems to be a consequence of the difference between the handgrip test and a quality of the grip done in the combat. However, the values presented by the elite judo athletes in the present study was lower than that reported by Claessens *et al.* [7] in high level Belgian judo players (right hand grip=64.9±8.9 kgf; left hand grip=59.7±8.8 kgf), indicating that the elite judo athletes from the present study could improve their hand grip isometric strength in order to attain an international profile.

Relative mean power and peak power were higher in the elite compared to non-elite judo athletes, confirming partially the hypothesis of higher power output for athletes with higher arm, forearm and wrist circumferences. Horswill *et al.* [15] also found higher mean and peak power output for elite wrestlers compared with non-elite ones. This result is in accordance with the assumption that the Wingate test performance is related to anaerobic power and capacity [16] and those judo athletes should have a high glycolytic energy transfer system to support the fight requirements [26]. It is important to note that the development of higher peak power is important to keep higher mean power, because the fatigue index was the same in both groups. However, it must be considered that the low effect size for mean and peak power, which indicated that the differences are not so evident. However, Borkowsky *et al.* [8] did not find any difference in lower body Wingate tests between Polish National winners and second and third placers. The difference between Borkowsky *et al.* [4] findings and ours might be related to the following aspects: (1) they compared the very best Polish judo athletes among them while we compared medal winners in National/International Tournaments with nonmedallists in those competitions; (2) there is a possibility that elite judo players differ in upper body anaerobic performance as we found, but not in lower body anaerobic performance as reported by Borkowsky *et al.* [4].

Another important point is that the values presented by both the elite and non-elite judo athletes of the present study were lower than those presented by the Canadian Team (relative mean power=8.66±1.17 $W\cdot kg^{-1}$; relative peak power=11.3±0.8 $W\cdot kg^{-1}$) [26] and by the British Team (relative mean power=8.50±0.50 $W\cdot kg^{-1}$; relative peak power=10.6±0.8 $W\cdot kg^{-1}$) [22], confirming the high arm anaerobic power and capacity for elite judo athletes. Another study [11] found a moderate correlation ($r=0.69$; $p<0.05$) between blood lactate after two upper body Wingate tests and blood lactate after a judo combat in high level college judo players.

In the judo specific test, the elite athletes also presented more anaerobic capacity (inferred from number of throws). This difference revealed a higher effect size (1.25), indicating the importance of this variable for judo athletes' evaluation. Heart rate did not differ between the groups, suggesting a similar cardiovascular stress during this test for both groups. This result may indicate a similar aerobic fitness presented by the groups. Consequently, the index was lower for the elite compared to non-elite judo athletes. The higher specificity of movements and the similarity of time structure of the SJFT with the judo combat seem to explain the difference between the groups and indicate that this test should be used for training control and talent identification in judo. An earlier study by Sterkowicz [25] found that Polish National medallists also presented a higher number of throws and a better index in the Special Judo Fitness Test compared with non-medallists from the Polish National Team. Furthermore, in Sterkowicz's [25] study, the heart rate recovery in 1 min was faster in the medallists than in non-medallists, suggesting that the recovery process could be another important difference between elite and non-elite judo players. In an earlier study, this test showed a similar blood lactate to those observed during the fight [11]. A high correlation ($r=0.82$; $p<0.05$) was also found between blood lactate after the SJFT and after a judo combat in top level judo players [11], indicating that this test seems to have the same glycolytic requirement that in judo combat.

The aerobic fitness, as evaluated by aerobic power (VO_2max) and aerobic capacity (VAT), was not different between the groups, suggesting that this variable is not a discriminatory one or is not so important during judo performance, as suggested by Borkowsky *et al.* [4]. Another explanation should be the fact that those athletes presented this variables well developed for judo performance, because those values were similar to the ones found in high-level judo athletes (59.2 ± 5.18 $ml\cdot kg^{-1}\cdot min^{-1}$) [27]. This last hypothesis seems to be more plausible, because Muramatsu *et al.* [20] found a good influence of aerobic power on high intensity intermittent performance in judo players. Gariod *et al.* [12] found that judo athletes with higher VO_2max presented a faster CP resynthesis (31 P NMR) compared with judo athletes with lower VO_2max. This can be important in intermittent tasks as judo, when the athlete must perform many high intensity efforts with brief time to recover. Similar results were found in studies on non-judo players [28].

Blood lactate did not differ between the elite and non-elite judo athletes, suggesting that the recovery process seems to be the same for those athletes and this can be interpreted because of the same aerobic fitness, which was proposed to improve blood lactate removal, especially in longitudinal studies [28]. Peak blood lactate after judo combat was a little higher than found in Australian judo athletes (7.1±2.0 $mmol \cdot l^{-1}$) [29] and French judo athletes (9.87±2.01 $mmol \cdot l^{-1}$) [27] after judo combat simulations, similar to that found after judo competition in the Polish Championships (10.4±4.4 $mmol \cdot l^{-1}$) and lower than the ones observed after international competitions (13.6±2.3 $mmol \cdot l^{-1}$) [23]. The lower blood lactate after active recovery compared to passive recovery was expected, because this kind of recovery has been associated with higher lactate consumption by active muscle mass, cardiac muscle mass and liver [1,13]. However, there is no agreement in the literature about the subsequent performance after active recovery compared with passive recovery [1,3,30]. The time when the difference in blood lactate between the active and passive recovery started in the presented study was faster than reported before (10-12 min) [13,16], probably because of a bigger sample in this study (n=46) compared to previous studies (n=6-10).

In conclusion, together with technical and tactics training, judo athletes should focus on improving their arm segment circumferences, general arm anaerobic power and capacity, and judo specific anaerobic capacity. Furthermore, active recovery (70% of velocity of anaerobic threshold) can help to remove blood lactate faster than just the usual passive recovery performed by athletes during competitions. However, this procedure must be investigated more to verify the possible benefits on subsequent performance.

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Accepted for publication 30.01.2004

Acknowledgements

The authors would like to thank the athletes and their coaches for their kind cooperation. Partially Supported by FAPESP (99/06408-2)