Specific exercise testing in judo athletes

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B Data Collection
C Statistical Analysis
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Abstract

Background and Study Aim: All-out exercise tests lasting the duration of a judo match, i.e., 5 minutes, regarding arm and leg performance have barely been introduced. We hypothesised that, besides body composition, arm and leg performance, derived from 5 minutes lasting all-out ergometric tests, would be of importance for success in judo competitions.

Material/Methods: The groups investigated consisted of eight juvenile (15.3±0.9 years) and six adult (25.2±4.9 years) male Austrian judokas of different ranks. In addition to body composition, power output and peak oxygen uptake (VO_2peak) were determined during 5-min all-out tests on an arm crank and a cycle ergometer.

Results: Relative VO_2peak during cranking was about 18% higher in juvenile than in adult men (35.5±4.3 $ml \cdot kg^{-1} \cdot min^{-1}$ *vs.* 30.0±3.5 $ml \cdot kg^{-1} \cdot min^{-1}$, $p \leq 0.05$). However, neither body composition nor arm and leg performance was related to competition success in juvenile judo athletes. In contrast, in adult judokas percentage of body fat ($r = -0.83$) and relative maximum arm power ($r = 0.83$) were both related to competition rank ($p \leq 0.05$).

Conclusions: As these results indicate age-related differences in the assessed determinants of success for judo competition performance, they may have practical importance and should be considered in planning the training for male judo athletes of different age classes.

Key words: ergometry • upper and lower body performance • judo performance • determinants of success • martial art • combat sport

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Background

Judo is a martial art and an Olympic sport that has recently, in August 2010, been enclosed in the program of the inaugural Summer Youth Olympic Games, for juveniles aged 14–18 years. Competitors are organized in age classes and weight divisions. Besides psychological and emotional components, technical skills, and tactical strategies, certain physiological characteristics are indispensable for success in training and competition, including coordination, flexibility, strength, velocity, and aerobic and anaerobic endurance [1–3]. A high level of physical fitness is required to support technical ability and offset fatigue to maintain performance and to prevent injuries throughout the combat with a regular duration of 5 minutes for adults.

The assessment of physical fitness of judo athletes using field tests, even if sport-specific, has the inconvenience of a low validity and reliability in comparison to the assessment in a laboratory setting. Only a few studies tried to assess male adult judokas performance using sport-specific ergometric tests with regard to total duration and time structure, i.e. intermittent effort [4–6]. However, peak oxygen uptake (VO_2peak) was not determined and other maximal performance parameters, not being the primary aim of those studies, could hardly be assessed using such protocols.

To our knowledge, only Little [7] and Franchini et al. [8] have investigated age-dependent differences between male judo competitors, but the ergometric tests used where not of combat duration.

Whereas most of these studies did not investigate the relationship between assessed parameters and judo competition performance, Callister et al. [9] identified body fat percentage as a discriminator of success in adult male weight-limited divisions. Taylor and Brassard [10] reported a low correlation between success in international competitions and adult elite judokas' physiological performance parameters, such as maximum oxygen uptake (VO_2max), leg strength, muscular endurance, flexibility, blood lactate, and time to exhaustion during an anaerobic run. Also for younger competitors **determinants of success** could hardly be detected. Lech et al. [11,12] identified just one parameter, i.e. time to reach maximal anaerobic power, to be related to the level of achievement in judo competitions only among junior (16–18 years) but not among cadet (14–16 years) contestants. Unfortunately, the laboratory tests used during these researches were generally different in duration compared to judo fights. Our previous study [13] is the only one which compared performance of male judo athletes belonging to different age classes by a sport-specific **ergometry**. However, it has not been verified if the assessed parameters correlated with competition performance. To our knowledge, no study has focused on determinants of success in judo athletes derived from sport-specific ergometric testing.

Determinants of success – Factors which concur to and are fundamental for the victory in a sports competition, i.e., a judo competition.

Ergometry – "The study of physical work activity, including that performed by specific muscles or muscle groups. The studies may involve testing with equipment such as stationary bicycles, treadmills, or rowing machines" [29].

Thus, the aim of this study was to evaluate body composition and performance parameters of male judo athletes, derived from 5 minutes lasting all-out arm and leg ergometric tests, as potential determinants of success for judo performance in two different age classes.

Material and Methods

Experimental approach to the problem

The present work was designed to study the differences in most commonly assessed body composition and ergometric performance parameters between juvenile and adult male judo athletes and to relate these results to judo performance. Therefore, the test protocols were developed to reproduce competition-like physical loads concerning intensity, duration, and involved muscle groups. Even if judo fights in the adult class typically lasts near to 3 minutes of effective time plus 1 min-1 min 40 sec of brakes [6,14,15], adult competitors have to be prepared to sustain a 5-min (+3 min in case of parity) regular duration match, and juvenile judoka, in the age class under 17 years, a 4-min (+2 min in case of parity) match. Moreover, also training fights generally adopted by judo coaches, in particular at the highest level of this sport (i.e., training camps of the International Judo Federation), last 5 min. Therefore, a 5-min all-out test on a cycle ergometer was used to assess leg performance and a body weight-depending incremental test on an arm crank ergometer was used to assess arm performance.

Even if allometric scaling techniques may allow a more appropriate method to adjust VO_2max and other performance parameters for body size, normative data are not as readily available as for ratio standard techniques [16]. Furthermore, as in judo competitors are organized in weight divisions, performance parameters related to body weight seem to be determinant for judo performance and were therefore calculated in the present study.

Subjects

The group investigated consisted of 14 healthy, male judo athletes from an Austrian sports club of different ages and experience: 8 juveniles (age class: cadets, U17), and 6 adults (age class: seniors, +20). Amateurs as well as competitive, non-professional judokas from regional up to the international level participated in this study. One athlete of the Austrian National Team was included in each age class. Juveniles trained judo 3.3±2.0 times a week, adults 5.8±2.9 times a week. Each judo-training session was used to be of quite high intensity and lasted 1.5 hours for both age classes. Moreover, 6 juvenile and 4 adult judokas absolved an additional strength training 1 to 3 times a week. The rank order was based on regional ranking lists specific for each age class. Main characteristics of the participants involved in this study are summarized in Table 1.

All testing procedures were conducted in the afternoon and in the first stage of the competitive period. Athletes were normally hydrated at the time of testing, had a light meal at least 2 hours before, and avoided heavy exercise on the day prior to and day of testing. Informed consent was obtained from each participant or the parents, if the athlete was a minor, prior to voluntary participation in the performance assessment program. The study was approved by the Institutional Review Board and conducted in accordance with the guidelines of the Declaration of Helsinki.

Procedures

First of all the spirometer was calibrated according to the manufacturers' instructions.

Anthropometry and body composition

After clinical routine examinations, body height, and body mass were assessed using standard techniques. A tetrapolar, multi-frequency bioelectrical impedance analysis (BIA 2000, Data Input GmbH, Germany) was used to determine percentage of body fat (%fat) following manufacturers' recommended procedures before starting the exercise tests.

Table 1. Judokas' main characteristics.

	Juvenile men (n=8)	Adult men (n=6)	Cohen's d
Age (years)	15.3±0.9	25.2±4.9**	3.30
Judo Training Experience (years)	8.9±2.0	16.5±3.7**	2.90
Height (cm)	174.4±5.1	176.5±6.5	0.40
Body Mass (kg)	62.8±4.4	77.5±11.2**	1.99
BMI ($kg \cdot m^{-2}$)	20.4±0.4	24.8±2.7**	2.69
Body Fat (%)	10.3±2.9	12.9±5.8	0.65

Values are mean ±SD for age, judo training experience, height, body mass, body mass index (BMI) and percentage of body fat, and judo training experience. Significant differences between juvenile and adult men: * p≤0.05; ** p≤0.01.

Test for the upper body

The upper body test has been used in our laboratory for several years to evaluate upper body performance of different athletes, such as judokas and climbers [13]. It was preceded by a standardized, non-specific warm-up (10 min running or cycling followed by 5 min of stretching exercises) and a specific warm-up (2 min cranking at 25 W on the test-ergometer immediately before starting the assessment program). The protocol consisted of a continuous incremental test using an arm crank ergometer (Ergometrics er800SH, Ergoline, Germany). While the starting power of 25 W was the same for all participants, the increment of power per minute corresponded to half of the value of the body mass, with gradual increment units of 5 W at regular time intervals, intending to reach a test duration of about 5 min. As power output is influenced by muscle mass and therefore by body weight, body weight-dependent power increments aimed to a similar test-duration for all participants, independent from their body mass and absolute power. The test ended when, due to exhaustion, a cranking frequency above 40 revolutions per minute could no longer be maintained. Maximum power at the end of the test (Pmax) and total crank time to exhaustion (Time) were recorded. The highest oxygen uptake and minute ventilation (VO_2peak and VEpeak) were determined as the averages of 30 s during the final phase, i.e., 4th and 5th min, shortly before breaking off the test by breath-by-breath measurements (Oxycon Alpha, Jaeger, Germany). Heart rate was monitored continuously during the exercise test (Polar, Finland). The highest heart rate observed was defined as peak heart rate (HRpeak). Heart rate reserve (HRR) was calculated using the formula: (220-age)-HRpeak.

Test for the lower body

The lower body test was performed after at least a 1-hour break following the upper body test. Because of the larger muscle mass involved during the test on the cycle ergometer, to reduce the negative effect of fatigue on performance, the sequence of the two tests was always the same. The protocol consisted of a 5-min maximum test on an electrodynamically-braked cycle ergometer (Excalibur Sport, Lode, Netherlands) [17]. The test-retest reliability is quite good, having intra-class correlation coefficients of $r>0.94$, $p<0.001$ [17]. The handle bar and saddle of the cycle were individually adjusted. The specific warm-up consisted of pedalling at a self-selected pace for 3 min at a power of 70 W immediately before starting the test. On the basis of pre-tests and of our broad experience in testing athletes of different age, the braking torque was then set at 0.3 and 0.5 N·m × body mass for juveniles and adults, respectively, and was held constant throughout the test. Participants controlled power output via the pedalling rate. The acceleration and deceleration of the flywheel mass were automatically taken into consideration for power output determination. Participants were encouraged to choose a maximal pedalling rate that could be maintained for the entire test duration. Mean power was the average power output for the 5-min period. VO_2 and VE were measured breath-by-breath during the 4th and 5th min of the test in order to determine peak values (VO_2peak and VEpeak) using an open spirometric system (Oxycon Alpha, Jaeger, Germany). The highest heart rate registered during the test (Polar, Finland) was defined as HRpeak. Heart rate reserve (HRR) was calculated using the formula: (220-age)-HRpeak.

Statistical analysis

Standard descriptive statistical procedures were used to determine mean ± standard deviation (mean ±SD) values for juvenile and adult men. Because the sample size was small and the data were not homogeneous, Mann-Whitney U-tests were used to evaluate differences between means of the two groups. Simple correlation coefficients by Spearman and by Pearson were determined for qualitative and for quantitative variables, respectively. To assess effect size, Cohen's d was calculated for differences between two means. Statistical significance was set

Sports Performance – "Carrying out of specific physical routines or procedures by one who is trained or skilled in physical activity. Performance is influenced by a combination of [physical], physiological, psychological, [emotional], and socio-cultural factors" [30].

Martial arts – "Systems of codified practices and traditions of combat, initially created for warrior purposes, and nowadays practiced for a variety of reasons, including self-defence, competition, physical conditioning etc." [31].

Combat sports – "Competitive contact sports where two combatants fight against each other using certain rules of engagement" [32].

Table 2. Judokas' ergometry performance.

	Juvenile men (n=8)	Adult men (n=6)	Cohen's d
Upper Body			
Pmax (W)	161.3±10.3	210.0±14.5**	4.30
Pmax (W·kg-1)	2.6±0.2	2.8±0.3	0.88
Time (s)	267.5±23.2	308.1±44.2	1.31
VO_2peak (ml·min^{-1})#	2213.8±150.5	2303.5±233.6	0.51
VO_2peak (ml·kg^{-1}·min^{-1})#	35.5±4.3	30.0±3.5*	1.49
VEpeak (l·min^{-1})#	89.0±18.3	82.2±13.9	0.44
HRpeak (beats·min^{-1})	172.9±11.1	152.5±7.6**	2.25
Lower Body			
Pmean (W)	227.6±26.6	301.8±13.6**	3.62
Pmean (W·kg^{-1})	3.6±0.2	4.0±0.5	1.21
VO_2peak (ml·min^{-1})#	3088.0±300.7	3844.3±372.0**	2.46
VO_2peak (ml·kg^{-1}·min^{-1})#	49.4±5.7	50.2±6.4	0.14
VEpeak (l·min^{-1})#	131.3±19.6	175.5±25.4**	2.15
HRpeak (beats·min^{-1})	188.6±9.2	175.7±4.6*	1.83

Values are mean ±SD for maximum power (Pmax), mean power (Pmean), test duration (Time), peak oxygen uptake (VO_2peak), peak ventilation (VEpeak), and peak heart rate (HRpeak) assessed during upper and lower body ergometry. Significant differences between juvenile and adult men: * p≤0.05; ** p≤0.01. # These parameters were measured during the 4th and 5th min of the tests.

at p≤0.05. The program used for statistical analysis was SPSS (version 15.0.1; SPSS Inc., Chicago, USA, 2006).

Results

Anthropometry and body composition

Comparisons between the two age groups showed that juvenile men differed from adult men in body mass (62.8±4.4 kg *vs.* 77.5±11.2 kg, p≤0.01) and body mass index (BMI) (20.4±0.4 kg·m^2 *vs.* 24.8±2.7 kg·m^2, p≤0.01), but not in body height and %fat (see Table 1). Among adult men, %fat was positively related to age (r=0.905, p≤0.05).

Arm and leg ergometric performance

Table 2 shows the results of ergometric testing of upper and lower body (arms and legs).

The test duration at the arm crank ergometer was approximately 5 min for adults and close to 4.5 min for juvenile men, which corresponds roughly to the regular duration of a judo match for the respective age classes (see Table 2).

Absolute power values of juveniles were lower than those of adults in both tests (Pmax: 161.3±10.3 W *vs.* 210.0±14.5 W, p≤0.01; Pmean: 227.6±26.6 W *vs.* 301.8±13.6 W, p≤0.01). Relative maximal power of the arms was negatively related to %fat only in juveniles (r=–0.809, p≤0.05). Among adult men, relative power of upper and lower body were closely related (r=0.923, p≤0.01).

Concerning HRpeak values, juveniles yielded higher values compared to adults (during arm cranking: 172.9±11.1 beats·min^{-1} *vs.* 152.5±7.6 beats·min^{-1}, p≤0.01; during cycling: 188.6±9.2 beats·min^{-1} *vs.* 175.7±4.6 beats·min^{-1}, p≤0.05). In contrast, juveniles' and adults' heath rate reserve (HRR) was similar in both groups (during arm cranking: 31.9±11.2 beats·min^{-1} *vs.* 42.3±8.5 beats·min^{-1} respectively, n. s.; during cycling: 16.1±9.5 beats·min^{-1} *vs.* 19.2±2.6 beats·min^{-1} respectively, n. s.).

Relative VO_2peak during arm ergometry was significantly different between the two groups, being about 18% higher among the younger athletes (35.5±4.3 ml·kg^{-1}·min^{-1} *vs.* 30.0±3.5 ml·kg^{-1}·min^{-1}, p≤0.05). During cycling, juveniles had lower absolute values of peak oxygen uptake and peak minute ventilation than did adults (VO_2peak: 3088±301 ml·min^{-1} *vs.* 3844±372 ml·min^{-1}, p≤0.01; VEpeak: 131.3±19.6 l·min^{-1} *vs.* 175.5±25.4 l·min^{-1}, p≤0.01). In both age classes, relative VO_2peak on the cycle ergometer was negatively related to age (juveniles: r=–0.741, p≤0.05; adults: r=–0.826, p≤0.05).

Determinants of success

Judo performance, i.e., the rank in judo competitions, of adult men was negatively related to %fat ($r=-0.829$, $p\leq0.05$) and positively related to relative Pmax of the upper body ($r=0.829$, $p\leq0.05$). No such determinants of success could be identified for juvenile men.

Discussion

The objective of the present study was to evaluate body composition and performance parameters of male judo athletes, derived from 5 minutes lasting all-out arm and leg ergometric tests, as potential determinants of success for judo performance in two different age classes. The main results obtained showed that percentage of body fat and relative maximum arm power were both related to rank only in adult judokas. These parameters can therefore be considered as discriminators of success only for judo performance in adult men.

Anthropometry and body composition

Anthropometric parameters showed a large inhomogeneity between and within the tested groups. This aspect is typical of judo and of sports with weight divisions in general [1,2].

The BMI of the adult men in our study (24.8±2.7 $kg \cdot m^{-2}$) was somewhat lower than that of Polish elite senior male judokas (26.4±1.6 $kg \cdot m^{-2}$) [18].

Percentages of body fat in this study (10.3±2.9% and 12.9±5.8% for juvenile and adult men, respectively) were comparable to data reported in the literature: 10.2% in juvenile male judokas [7] and from 8.3% to 16.2% in adult male competitors [1,2]. However, it should be mentioned that body fat values in the literature were mostly derived from skinfold measurements, making direct comparisons difficult.

Anthropometric parameters of the tested judokas reflected typical age differences. Indeed, body mass and BMI were higher among adult athletes. In contrast, %fat showed no significant differences between age classes, despite the age-dependent increase in %fat among adults. This is also in accordance with trends reported in the literature where juvenile, junior, and senior male judokas had similar values for body fat [7].

Arm and leg ergometric performance

Since it seems that no one has studied power measurements during continuous or incremental laboratory tests lasting approximately the duration of a judo match, comparisons with the literature are difficult. The only available maximal power values of juvenile and adult male judokas, though determined during a 3-min step test at the arm crank ergometer, are of 1.63±0.11 $W \cdot kg^{-1}$ and 1.94±0.38 $W \cdot kg^{-1}$ respectively (n.s.) [8]. These values are somewhat lower than those of the present study, probably due to a longer testing duration.

Relative maximal power of the arms was negatively related to %fat among young men. As body composition influenced upper body performance, a loss in fat mass, primarily achieved through a higher training volume, could be useful to maximize relative muscle power. The strong relation between relative power of the upper and lower body among adult men seems to underline the general state of whole-body fitness of the tested athletes and could be considered a training adaptation, as both arms and legs are involved in judo. Correlations between upper and lower body performance parameters are reported in literature, but were significant only for absolute and not for relative values [19].

Because of the similar HRR, group-related differences in peak heart rate during both tests can be attributed to the age difference [20].

Even if methods of VO_2max assessment used in other studies on judo athletes are somewhat different from those used in the present study, from our experience in testing we can consider the VO_2peak measured during cycle ergometry to be very close to the VO_2max. Therefore, taking into consideration that the VO_2peak measured at the cycle ergometer could be 3–6% lower than values from the treadmill test [21,22], a comparison with data from the literature should be possible. Mean values of relative VO_2peak for the lower body of juvenile (49.4±5.7 $ml \cdot kg^{-1} \cdot min^{-1}$) and adult (50.2±6.4 $ml \cdot kg^{-1} \cdot min^{-1}$) male judo athletes in the present study fall within the lower region of the range of values reported in literature for age-matched male judokas of different competitive levels, from provincial to international level, ranging between 43.5 and 58.7 $ml \cdot kg^{-1} \cdot min^{-1}$ for juveniles [7,11,23] and between 40.0±5.5 and 64.9±5.5 $ml \cdot kg^{-1} \cdot min^{-1}$ for adults [1,2]. Values of tested athletes could roughly be compared to those of lower ranked, i.e., national-level, judo athletes.

Relative lower body VO_2peak decreased with age in each of the two groups. This trend is in accordance with data reported in the international literature which identifies the highest relative VO_2max values in males aged 15–20 years [20,21]. Similar results were also reported by Little [7], where juvenile (14.7±0.9 years) and junior (17.3±0.8 years) competitors had significantly higher relative VO_2max values, measured on a treadmill,

compared to senior judo athletes (26.0±5.3 years). As a possible explanation, the author proposed that training emphasis on technical and tactical skills in judo may be a more important performance factor for male judokas when progressing from junior to senior levels of competition. Despite these results [7], differences in relative VO_2peak during lower body work between groups did not reach significance in the present study. Nevertheless, these findings are in accordance with our previous results [13].

In contrast to lower body work, a higher relative VO_2peak during upper body work distinguished juvenile male judo athletes from adult judokas. These findings are perfectly in line with other studies performed at our institute using the same testing-protocol [13], but are in disagreement with Franchini et al. [8], who didn't find differences in upper body relative VO_2peak values between juvenile (16.3±0.8 years), junior (19.4±0.5 years), and senior (23.5±2.2 years) male judokas. To explain the present results, it could be speculated that more years and training volumes of judo practice of adults compared to juveniles (16.5 years, 5.8±2.9 times a week *vs.* 8.9 years, 3.3±2.0 times a week, respectively) and of strength training, with more emphasis of the upper body compared to the lower body, could have lead to specific muscle adaptations. Physiological mechanisms supposed to be involved have already been discussed in our recent investigation [13].

Determinants of success

Judo performance was inversely related to %fat and directly related to maximal upper body power relative to body weight (arm cranking) only among adult men. The first relation is in accordance with a study where the only parameter significantly related to elite judokas' rank was the %fat among male competitors in weight-limited divisions [9]. Moreover, male junior elite wrestlers could also be distinguished from non-elite wrestlers on the basis of skinfold thickness [24]. However, the authors did not hypothesise if this trend was due to differences in training or in making weight [24].

The higher relative arm Pmax among more successful adult male judokas could contribute to the relevance of upper body power in the grip fight and during the combat in general, when competitors have to maintain an advantageous distance from the opponent, extending or flexing the elbow [25]. This finding may also be partly due to the higher importance focused on strength training and to a higher amount and frequency of judo practice with increasing age and rank. Apparently, only one study on judo athletes reported similar results during an aerobic-anaerobic task for the upper body [26] and such findings were also reported for wrestlers [24]. Moreover, Callister et al. [9] identified a similar, although not significant, trend among adult female judokas concerning arms strength, especially at higher velocities. Similar results are also reported by Kubo et al. [25], who measured larger arms muscle thicknesses in judo athletes with a higher performance level. However, the majority of studies concerning judokas did not clearly define variables that discriminate between higher and less successful athletes [10,11,27]. Moreover, from the results of prior studies, it can be assumed that judokas do not represent a homogeneous group and their physical and physiological parameters show specific trends across the different weight divisions [9,19]. Because of these differences, further studies are necessary to evaluate predictors of success related to competitive weight divisions [9].

As no such determinants of success were identified for the juvenile age class, which is in accordance with literature [11], we assume that ergometric predicting parameters differ between young age and adulthood in a quite homogeneous group of non-elite male judokas. Maybe the identified determinants of success could distinguish between competitors whose judo experience is in general quite high, but not between younger athletes, whose judo performance could probably depend more on other factors like technical and tactical level [11], competition experience or psychological factors.

Because of different testing protocols, it is not possible to compare all measured parameters to those found in the literature. It would be interesting to carry on this research by performing the same tests, or a similar test protocol for arms and legs, to compare upper and lower body performance parameters. Further parameters, i.e., blood lactate, should be measured in order to determine the contribution of the anaerobic lactic energy system. Moreover, the chosen test-protocols, even if of match duration and quite easy to be reproduced, don't reflect exactly the intermittent nature of judo matches and of judo competition. However, it should be mentioned that the minimal recovery time of 15 min typically reported in judo competitions [26] seems to be long enough for a full performance recovery of highly trained judokas [28]. Moreover, the meaning of the obtained results could be limited by the small sample size, which may influence some correlations. A higher number of participants among each subgroup, possibly representing all weight divisions, would be advantageous, especially for defining the predictors of success. However, this study represents a first step in the development of simple, specific ergometric tests for upper and lower body performance designed for judo athletes.

Conclusions

Our results demonstrate an important role of specific ergometric testing especially in adult male judo athletes and indicate age-related differences in the assessed determinants of success for judo competition performance. These results may have practical importance and should be considered in planning the training for male judo athletes of different age classes.

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