Sex-differences in response to arm and leg ergometry in juvenile judo athletes

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

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Source of support: University Grant (Doktoratsstipendium), third-party funds (TWF, i.e., Tiroler Wissenschaftsfonds), departmental sources and authors' own financial resources

Received: 18 April 2013; **Accepted:** 28 June 2013; **Published online:** 10 August 2013

ICID: 1062242

Abstract

Background & Study Aim: Literature deals barely with sex-related differences of young judokas concerning physiological data from laboratory tests. Therefore, the aim of this study was to acquire knowledge about potential similarities and differences of juvenile male and female judo athletes, derived from all-out arm and leg ergometric tests of combat duration.

Material & Methods: Maximum power output (Pmax) and physiological indicators, i.e., peak oxygen uptake (VO_2peak), peak ventilation (VEpeak), peak heart rate, post-exercise lactate (LA), and rate of perceived exertion (RPE), of 17 male (14.0±1.4 years) and 6 female (13.8±1.3 years) juvenile Austrian judokas were assessed during incremental tests of combat duration (~ 3-4 min) on an arm crank and a cycle ergometer.

Results: Juvenile men had about half of women's %fat (10.6±3.3% vs. 20.2±3.8%, $p \leq 0.01$), higher values of relative Pmax (2.5±0.3 $W \cdot kg^{-1}$ vs. 2.0±0.2 $W \cdot kg^{-1}$, $p \leq 0.01$), absolute and relative VO_2peak (2201.9±559.0 $ml \cdot min^{-1}$ vs. 1667.2±341.5 $ml \cdot min^{-1}$, $p \leq 0.05$ and 38.4±4.9 $ml \cdot kg^{-1} \cdot min^{-1}$ vs. 29.8±4.6 $ml \cdot kg^{-1} \cdot min^{-1}$, $p \leq 0.01$), relative VEpeak (1.6±0.3 $l \cdot kg^{-1} \cdot min^{-1}$ vs. 1.2±0.3 $l \cdot kg^{-1} \cdot min^{-1}$, $p \leq 0.01$), and LA (9.3±2.5 $mmol \cdot l^{-1}$ vs. 6.5±1.2 $mmol \cdot l^{-1}$, $p \leq 0.05$) during cranking and higher values of relative VO_2peak (51.8±6.0 $ml \cdot kg^{-1} \cdot min^{-1}$ vs. 45.3±4.5 $ml \cdot kg^{-1} \cdot min^{-1}$, $p \leq 0.05$) and RPE concerning breathing effort (16.4±1.6 vs. 14.6±1.5, $p \leq 0.05$) during cycling.

Conclusions: The present results demonstrate sex-specific differences performance indicators assessed during arm and leg ergometry of combat duration in juvenile judo athletes. These findings may have practical importance and should be considered in evaluating the results from ergometric testing as well as in planning the training for young male and female judo athletes.

Key words: specific exercise testing · upper and lower body performance · martial arts · combat sports · gender differences

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Background

Judo is a martial art and an Olympic sport with an increasing number of high level competitions for juvenile athletes; i.e., it has recently, in August 2010, been enclosed in the program of the inaugural Summer Youth Olympic Games, for juveniles aged 14-18 years [1-3]. 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 [4-6]. 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 [3], with a regular duration of 2-5 min, depending on the age class, plus the eventual extra time when the initial period is finished in

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" [3].

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." [1].

Combat sports – "Competitive contact sports where two combatants fight against each other using certain rules of engagement" [23].

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" [22].

parity. Also a judo training of the duration, usually, comprised between 1.5 and 2 hours, elicits the anaerobic as well as the aerobic system [7]. However, only a couple of studies tried to assess male judokas' performance, including peak oxygen uptake (VO_2peak), using sport-specific ergometric tests with regard to total duration, intensity, and involved muscle groups [2,3]. Anyway, female judo athletes have not been investigated [2,3]. Generally, anthropometrical and physiological data on female judokas are quite rare [8,9].

During competitions, contestants are divided by sex, sometimes by grade or judo experience, and organized in age classes and weight divisions. Nevertheless, during judo training sessions in the sports clubs as well as in national teams or at training camps, athletes are usually divided according to performance level or grade and age, but not by sex. Coaches often try to improve the quality of judo training in order to increase performance level of the competitors starting from juvenile age, but usually without taking into account sex as an aspect of individuality in sport, which should be considered among the factors having an influence on judo performance as well as on sport performance generally [10,11].

Little research is available comparing anthropometrical and physiological profiles of male and female judokas, but focused mostly on competitors of national teams, i.e., adult athletes [10,12,13]. Male contestants of the U. S. judo team differed from their female peers having a lower percentage of body fat (%fat), a higher absolute but not relative maximal oxygen uptake (VO_2max), and a lower maximal heart rate (HRmax) [12]. Furthermore, men were stronger, with a higher percentage of type IIB muscle fibres in comparison to women, who had a higher relative quantity of type I fibres [12]. Similarly, a lower %fat distinguished men and no significant differences could be shown concerning relative VO_2max of Algerian Olympic judokas belonging to the two sexes [13]. Also male judokas of the Italian Olympic team were characterized by having a higher absolute but not relative VO_2max in comparison to the female competitors [10]. However, the small sample size and unequal distribution of weight categories could have influenced that result. Nevertheless, even if knowledge on sex-related differences in judo athletes' body composition is consolidated [5], mentioned data on relative VO_2max are not corroborated by review studies, which indeed showed male judokas having higher values than their female counterparts [4,5].

Further studies investigated anthropological and fitness status of elite judo athletes of both sexes, but did not draw comparisons between sexes [14,15]. Also, data on anthropometrical profiles and physical performance of male and female competitors of different age classes are very scarce [1,16]. Again, authors did not compare data between sexes [16] or limited the sex-specific comparison to anthropometrical data, however without considering age classes separately [1].

Therefore, the aim of this study was to gain knowledge about the similarities and differences of body composition and performance parameters of juvenile male and female judo athletes, derived from all-out arm and leg ergometric tests of combat duration.

Material and Methods

Experimental approach to the problem

The test protocol was adopted from our recent investigation [2] to reproduce match-like physical loads concerning duration and involved muscle groups. As absolute power output is influenced by muscle mass and therefore by body mass, body mass-dependent power increments aimed to achieve a similar test-duration, i.e. combat duration, for all subjects. The same incremental protocol was used for arms and legs but, as on the basis of our testing experience [2,3,17] lower body maximum power was supposed to be about twice of upper body maximum power, values of load increment per minute at the arm crank ergometer were half of the values at the cycle ergometer, in order to reach about the same test duration. The ergometry with a continuous incremental load and total duration between 3 and 4 min, depending on fitness status, imply that the tests were mainly aerobic [2].

Subjects

The test group investigated consisted of 23 injury-free, healthy, male and female juvenile athletes of the two major judo clubs of the Austrian region of Tyrol. Characteristics of tested judokas of both sexes are reported in Table 1.

All subjects were physically very active and trained judo 2-3 times a week. Each judo-training session was of quite high intensity and lasted 1 h 30 min for all subjects. They all had competitive experience in judo tournaments at local, regional, national and some of them, men as well as women, also at international level. The athletes were made familiar with arm cranking prior to testing. All judokas were familiar with cycling even if they performed the proposed test protocol for the first time.

Table 1. Judokas' main characteristics.

	Juvenile Men (n=17)			Juvenile Women (n=6)				Cohen's d
Age (years)	14.0	±	1.4	13.8	±	1.3		0.15
Judo Training Experience (years)	7.1	±	1.6	6.5	±	1.0		0.43
Height (cm)	169.0	±	12.5	165.3	±	4.5		0.35
Body Mass (kg)	57.4	±	12.6	55.8	±	5.5		0.15
BMI ($kg \cdot m^{-2}$)	19.7	±	2.0	20.4	±	2.0		0.37
Body Fat (%)	10.6	±	3.3	20.2	±	3.8	**	2.93

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

All testing procedures took place at the performance diagnostic laboratory of the Department of Sport Science of the University of Innsbruck and were conducted in the afternoon, at the end 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 on the day of testing. Written informed consent was given from parents of all subjects prior to their voluntary participation in the testing program. The study was approved by the Institutional Review Board and conducted in accordance with the 2008 revision of the Helsinki Declaration.

Procedures

Anthropometry and body composition. After clinical routine examinations, stature and body mass were assessed using standard techniques. A tetrapolar, multi-frequency bioelectrical impedance analysis (BIA 2000, Data Input GmbH, Darmstadt, Germany) was used to determine percentage of body fat (%fat) following manufacturers' recommended procedures. A capillary blood sample from the ear lobe was collected in order to determine resting concentration of blood lactate (LA) before starting the exercise tests.

Test for the upper body. The upper body test [2,3] was preceded by a standardized, non-specific warm-up, i.e. 10 min running or cycling, followed by 5 min of stretching exercises, and a specific warm-up, i.e. 3 min on the test-ergometer at a power corresponding to 0.5 $W \cdot kg^{-1}$ of body mass, immediately before starting the assessment program at the same power of 0.5 $W \cdot kg^{-1}$. The protocol consisted of a continuous incremental test using an arm crank ergometer (Ergometrics er800SH, Ergoline, Bitz, Germany) [2,3]. The increment of power was of 0.5 $W \cdot kg^{-1} \cdot min^{-1}$, with gradual increment units of 5 W at regular time intervals, intending to reach a total test duration between 3 and 4 min. The test ended when, due to physical or psychological 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. Oxygen uptake (VO_2) and minute ventilation (VE) were determined as the averages of 30 s by breath-by-breath measurements (Oxycon Mobile, Jaeger, Höchberg, Germany) in order to determine peak values of oxygen uptake (VO_2peak) and minute ventilation (VEpeak). Heart rate was monitored continuously during the exercise test (Polar S810i monitor, Polar Electro OY, Kempele, Finland). The highest heart rate observed was defined as peak heart rate (HRpeak). At the end of the test, athletes expressed their rate of perceived exertion for breathing effort (RPE-Br) as well as for muscle pain (RPE-Mm) pointing on a Borg Scale of 6-20. Then athletes continued to crank against a low resistance for about half-minute in order to cool down. Three minutes after the end of the test, a blood sample was collected from the ear lobe for the measurement of LA (Biosen C-Line, EKF Diagnostics GmbH, Barleben, Germany).

Test for the lower body. The lower body test was performed after at least a 1-hour break following the upper body test. Considering that this test involves a larger muscle mass than the test at the arm crank 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 continuous incremental test on an electrodynamically-braked cycle ergometer (Ergoselect 100, Ergoline, Bitz, Germany) [2]. 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 1 W·kg^{-1} of body mass. Then the test started immediately at the same power of 1 W·kg^{-1}, with gradual increment-units of 5 W at regular time intervals, corresponding to 1 W·kg^{-1}·min^{-1}, intending to reach a total test duration between 3 and 4 min. Subjects were free in choosing the optimal pedalling rate above 50 revolutions per minute; when the pedalling rate sank below this value the test ended. Pmax and total cycling time to exhaustion (Time) were recorded. Physiological and perceptual responses to exercise were measured as described for upper body testing.

Ratios. The ratio between upper and lower body maximum power and the ratio between upper and lower body VO_2peak were calculated for all subjects.

Statistical analysis

Standard descriptive statistical procedures were used to determine mean ± standard deviation (mean ± SD) values for men and women. After proofing of normal distribution, T-tests were used to evaluate differences between means of the two samples. Simple Correlation Coefficients by Pearson were calculated to determine relationships between variables. To assess effect size, Cohen's d was calculated for differences between two means. Statistical significance was set at $p \leq 0.05$. SPSS (version 18, SPSS Inc., Chicago, USA) was used to perform analyses.

Results

Anthropometry and body composition

Comparisons between the two groups showed that juvenile women differed from juvenile men only in body fat percentage, which was about double among female athletes (Table 1).

Moreover, considering the whole sample of judokas, %fat was negatively related to Pmax/kg (r=-0.442, p=0.035), VO_2peak/kg (r=-0.482, p=0.020), LA (r=-0.414, p=0.050), and RPE-Mm (r=-0.463, p=0.026) during arm ergometry. On the other hand, such correlations could not be shown within the two samples of judo athletes considered separately.

Arm and leg ergometric performance

The mean test duration at the arm crank ergometer was 3 min 43 s for juvenile men and approximately 3 min for juvenile women (Table 2). The lower body test lasted on average 4 min 17 s for male and nearly 3 min 50 s for female judo athletes (Table 2).

The test at the arm crank ergometer showed men having higher values of relative maximum power (25.0%), absolute as well as relative VO_2peak (32.1% and 28.9%, respectively), relative VEpeak (33.3%), and LA (43.1%) compared to women. During cycling, male competitors had a 14.3% higher relative VO_2peak and a 12.3% higher RPE-Br than female athletes.

Significant correlations between performance parameters of the whole sample of judokas were found, i.e., between Pmax/kg of arms and legs (r=0.474, p=0.022), VO_2peak/kg of arms and legs (r=0.562, p=0.005), Pmax/kg and VO_2peak/kg of the arms (r=0.770, $p \leq 0.001$), Pmax/kg and VO_2peak/kg of the legs (r=0.754, $p \leq 0.001$), ratio between arms' and legs' maximum power and ratio between arms' and legs' VO_2peak (r=0.625, p=0.001). Similar correlations or trends were present also within each of the two samples of judo athletes.

Discussion

The main results showed juvenile men having about half of women's %fat, higher values of relative Pmax, absolute and relative VO_2peak, relative VEpeak, and post-exercise LA during arm ergometry, and higher relative VO_2peak and RPE-Br during cycle ergometry.

Anthropometry and body composition

Anthropometric indicators showed no differences between the two groups of coetaneous judokas regarding height and body mass. On the other hand, juvenile female competitors were characterized by twice of %fat compared to their male counterpart. This tendency is well known in the literature concerning judo athletes of different age classes as well as the general population [1,5,16]. Values of tested athletes are in accordance with data from previous studies, which showed male judo athletes at this age having 10.2±1.6% body fat [16] and about 16 years old female judo athletes having between 16.1±3.5% and 19.5±1.8% body fat [1,16]. However, it should be mentioned that body fat values in the literature [1,5,16] were mostly derived from skinfold measurements, making direct comparisons difficult.

As %fat was negatively related to Pmax/kg, VO_2peak/kg, LA, and RPE-Mm during arm cranking, it seems to have a negative influence on upper body performance. Therefore, considering that judo performance of male adult athletes is negatively affected by %fat and positively by arms' relative Pmax [3,12,18], a loss in excessive %fat, within the physiological range, could probably be an advantage also for young judo competitors. However, caution is

Table 2. Judokas' ergometry performance.

	Juvenile Men (n=17)			Juvenile Women (n=6)				Cohen's d
Upper Body								
Pmax (W)	142.9	±	39.8	114.2	±	16.6		0.85
Pmax (W·kg^{-1})	2.5	±	0.3	2.0	±	0.2	**	1.88
Time (s)	222.6	±	52.8	182.0	±	29.8		0.89
VO_2peak (ml·min^{-1})	2201.9	±	559.0	1667.2	±	341.5	*	1.09
VO_2peak (ml·kg^{-1}·min^{-1})	38.4	±	4.9	29.8	±	4.6	**	1.87
VEpeak (l·min^{-1})	90.6	±	27.3	69.0	±	20.2		0.88
VEpeak (l·kg^{-1}·min^{-1})	1.6	±	0.3	1.2	±	0.3	**	1.40
HRpeak (beats·min^{-1})	185.7	±	14.0	186.5	±	10.5		0.06
RPE-Br	14.1	±	2.5	12.9	±	2.0		0.53
RPE-Mm	17.0	±	1.7	16.0	±	0.8		0.69
LA (mmol·l^{-1})	9.3	±	2.5	6.5	±	1.2	*	1.31
Lower Body								
Pmax (W)	301.8	±	77.3	270.0	±	44.7		0.47
Pmax (W·kg^{-1})	5.2	±	0.6	4.8	±	0.4		0.75
Time (s)	257.2	±	39.8	228.8	±	23.2		0.82
VO_2peak (ml·min^{-1})	2949.3	±	661.9	2530.8	±	431.1		0.72
VO_2peak (ml·kg^{-1}·min^{-1})	51.8	±	6.0	45.3	±	4.5	*	1.20
VEpeak (l·min^{-1})	111.2	±	33.2	100.5	±	12.4		0.38
VEpeak (l·kg^{-1}·min^{-1})	1.9	±	0.4	1.8	±	0.2		0.29
HRpeak (beats·min^{-1})	189.1	±	9.6	193.5	±	10.7		0.47
RPE-Br	16.4	±	1.6	14.6	±	1.5	*	1.20
RPE-Mm	16.9	±	1.6	16.3	±	2.3		0.35
LA (mmol·l^{-1})	9.8	±	3.3	9.1	±	1.4		0.25
Ratios								
PmaxUB/PmaxLB (%)	47.5	±	6.9	42.7	±	5.4		0.77
VO_2peakUB/VO_2peakLB (%)	74.6	±	8.7	66.5	±	11.2		0.90

Values are mean ± SD for maximum power (Pmax), test duration (Time), peak oxygen uptake (VO_2peak), peak ventilation (VEpeak), peak heart rate (HRpeak), rate of perceived exertion for breathing effort (RPE-Br) and for muscle pain (RPE-Mm), blood lactate concentration 3 min post-exercise (LA), ratio between upper and lower body maximum power (PmaxUB/PmaxLB) and VO_2peak (VO_2peakUB/VO_2peakLB) assessed during upper and lower body ergometry. Significant differences between male and female juvenile judo athletes: *p≤0.05; **p≤0.01.

needed in the interpretation of these results as the mentioned correlations were present only among the total group of judo athletes, and not among juvenile men and women considered separately.

Arm and leg ergometric performance

The mean duration of the tests, comprised between 3 min and 4 min 17 s, corresponds roughly to the regular duration of a judo match for the age classes in which tested athletes competed: U15 (3 min) and U17 (4 min).

Regarding arm ergometry, juvenile male judo athletes reached an about 25% higher relative Pmax than female competitors. In accordance, Little [16] reported juvenile male judokas (14.7 ± 0.9 years) having an about 30% higher relative mean power than their female peers (15.5 ± 0.7 years), albeit assessed during an upper body Wingate test.

Also ventilatory indicators (absolute and relative VO_2peak, and relative VEpeak) measured during arm ergometry and lactate concentration 3 min after breaking off cranking were significantly higher among men compared to women. These data suggest that, in comparison to coetaneous female judokas, male competitors at this age reach a higher maximal physical power with the arms utilizing the aerobic as well as the anaerobic energy pathways. Indeed, it's well known from the literature that men reach higher VO_2peak values than women starting about from the 2nd decade of age [19].

Also during cycling men showed a 14.3% higher relative VO_2peak than women. The higher values of relative peak aerobic power are in accordance with data reported on juveniles, which show females reaching on average 75% to 85% of males' maximum values, i. e., men having about 18%-33% higher values than women [19]. A study on juvenile judo athletes tested on a treadmill, where young men had a 27.8% higher relative VO_2peak than women, seems to corroborate this trend [16].

RPE-Br during cycling was 12.3% higher in juvenile men than in women, which seems to be related to their higher aerobic performance (higher relative VO_2peak). In accordance to literature, the numerous correlations between performance indicators of upper and lower body and also between relative Pmax and VO_2peak of the arms as well as of the legs point out the general state of whole body fitness of judokas and could be attributed to an adaptation to judo training [3].

The chosen test-protocols, even if of match duration and quite easy to be reproduced, do not reflect exactly the intermittent nature of judo matches and competition. However, it should be mentioned that the minimal recovery time of 15 min typically reported in judo competitions [20] seems to be long enough for a full performance recovery of highly trained judokas [21]. Moreover, the meaning of the obtained results could be limited by the small sample size, especially among female athletes. A higher number of participants among each subgroup, possibly representing all weight divisions, would be advantageous for the statistical analysis, even if we are aware of the difficulties in recruiting a sufficient number of judokas, especially female ones. Furthermore, it would be also interesting to investigate differences between male and female judo athletes belonging to different age classes. Nevertheless, this study represents a first step in assessing sex-related differences in juveniles' body composition and performance indicators by means of simple, specific ergometric tests for upper and lower body performance designed for judo athletes.

Conclusions

The present results demonstrate sex-specific differences in performance indicators assessed during ergometric tests of combat duration in juvenile judo athletes. These findings may have practical importance and should be considered in evaluating the results from ergometric testing as well as in planning the training for young male and female judo athletes. In particular adequate sex-specific percentages of body fat should be considered when defining target competitive weight divisions for juvenile male and female judokas. Furthermore, physical demands during judo as well as additional strength and conditioning training for juvenile judo athletes, especially focusing on the upper body, should take into account the higher males' maximal arm power.

Acknowledgements

The authors would like to acknowledge the University of Innsbruck and the Tiroler Wissenschaftsfonds for the financial support, all the judo athletes who volunteered for this study and their trainers for the kind collaboration.

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Cite this article as: Pocecco E, Burtscher M. Sex-differences in response to arm and leg ergometry in juvenile judo. Arch Budo, 2013; 3: 181–187