



JUMPING ABILITIES AND POWER-VELOCITY RELATIONSHIP IN JUDO ATHLETES: COMPARATIVE ANALYSIS AMONG AGE CATEGORIES

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ABSTRACT

Purpose. The aim of the study was to examine age differences in the maximal power and height of rise of the body mass centre measured in spike jump (SPJ) and counter-movement jump (CMJ), and power-velocity relationship of lower extremities between cadet and U23 age class judo athletes. **Methods.** Seven cadets (age 16.6 ± 0.7 years) and eight U23 age class (21.3 ± 1.4 years) Polish judoists took part in the study. The maximal power and height of jump were measured at SPJ and CMJ jumps. Power-velocity relations ($P-v$) were determined from 5 maximal cycle ergometer exercise bouts at increasing external loads equal to 2.5, 5.0, 7.5, 10.0 and 12.5% of body weight (BW). **Results.** Cadet judoists had a significantly smaller maximal power output ($11.56 \pm 1.21 \text{ W} \cdot \text{kg}^{-1}$) than U23 athletes ($12.69 \pm 0.67 \text{ W} \cdot \text{kg}^{-1}$). The optimal velocity was similar in both group (119.3 ± 16.0 rpm and 119.6 ± 15.5 rpm, respectively). Significant age differences were founded between the cadet and U23 athletes for power output at external load equal 12.5% BW. Cadet judoists generated insignificantly lower maximal power in CMJ and SPJ than U23 judo athletes with except of the absolute maximal power in SPJ. The age difference was observed in height of CMJ. **Conclusions.** Based on the characteristics of $F-v$ curve we can see in which direction follow the effects of training. Application of CMJ and SPJ in jumping test allows to assess changes in neuromuscular coordination. The use of the both methods give better information to optimal training control.

Key words: force-velocity relationship, power output, judo, spike jump, counter-movement jump

Introduction

Success in judo requires perfect physical and tactical preparation [1, 2]. An essential element of the workshop, each coach should be the knowledge of potential competitors and the ability to choose the appropriate training loads. To determine motor abilities of athletes are necessary to use adequate testing and/or measurements. The measurement of the maximal static muscle torque and maximal power output of legs yields valuable information that can be extremely useful in judo training planning [3]. Professional literature includes a number of works comparing to the results of judoists with untrained [4–6], super elite with elite or elite with non-elite athletes [1, 7–9], female with male [6, 10, 11] and cadets, juniors and seniors [11–13]. Also, there is very little work comparing players at different stages of training [9, 12, 14]. Franchini et al. [11] in his publication called on even the need to increase the amount of work on the comparison of players of different ages groups (for example cadets and juniors).

The aim of the study was to examine age differences in the maximal power and height of rise of the body mass centre measured in spike jump (SPJ) and counter movement jump (CMJ), and power-velocity relationship of lower extremities between cadet and U23 age class judo athletes.

Material and methods

The study was granted approval of the Senate Ethics Committee of the Józef Piłsudski University of Physical Education in Warsaw. The subjects were informed about the scope and protocol of the study, and of the possibility to withdraw from the study at any moment, and the study was conducted in adherence to the Declaration of Helsinki. All subjects submitted their written consents to participate. Seven cadets and eight U23 age class Polish judoists took part in the study. Their mean (\pm SD) age, body height, body mass and training experience were 16.6 ± 0.7 years, 177.1 ± 7.4 cm, 75.9 ± 12.0 kg, 6.6 ± 2.4 years in cadets and 21.3 ± 1.4 years, 178.5 ± 11.3 cm, 86.1 ± 13.0 kg, 11.4 ± 3.1 years in U23, respectively. No significant differences were found between cadet and U23 judo athletes for body height and body mass but significant difference was observed between the groups for age and training experience.

The force-velocity ($F-v$) and power-velocity ($P-v$) relationships were determined on the basis of results of exercises performed on a Monark 874 E cycloergometer (Sweden) connected to a PC, using the MCE 4.0 software package („JBA” Zb. Staniak, Poland). After adjusting the ergometer saddle and handlebars each subject performed the tests in a stationary position, without lifting off the saddle, with his feet strapped onto the pedals. Each participant performed five 10-second maximal cycloergometer tests with increasing external loads amounting to 2.5, 5.0, 7.5, 10.0 and 12.5% of body

weight (BW), respectively. There were 2-min breaks between the tests. The standard procedures of exercise performance were followed, and the subjects were verbally encouraged to achieve and maintain as quickly as possible the maximal pedaling velocity. With the use of MCE v. 4.0 the maximal power output at a given load (P_i ; i – load value) and velocity (v_i) necessary to achieve P_i were determined [15–17]. On the basis of the obtained results the force-velocity and power-velocity relationships as well as individual maximal strength output (P_{max}) and optimal pedaling velocity (v_o) were calculated for each subject [15]. The maximal power output and optimal pedaling velocity were computed from individual equations of the second degree polynomial describing the P – v relationship [15]. The maximum of the curve (largest value of the function) was defined as maximal strength (P_{max}), relative and the pedaling velocity necessary to achieve it as optimal velocity. Absolute and relative power output recorded in (W) and ($W \cdot kg^{-1}$) respectively.

The power output of lower extremities and the height of rise of the body mass center during vertical jumps were measured on a force plate with a Kistler amplifier Type 9281A (Switzerland) for counter-movement jumps (CMJ) and spike jumps (SPJ). The amplifier was connected to a PC via an A/D converter. The MVJ v. 3.4. software package („JBA” Zb. Staniak, Poland) was used for measurement. In the physical model applied the subject's body mass bouncing on the platform was reduced to a particle affected by the vertical components of external forces: the body's gravity force and the vertical component of the platform's reactive force. The maximal power (P_{max} [W]), relative maximal power ($P_{max} \cdot mass^{-1}$ [$W \cdot kg^{-1}$]) and maximal height (h [m]) of rise of the body mass

center (COM) were calculated from the registered reactive force of the plate [17–19]. Each subject performed six vertical jumps with maximal force on the force plate: three counter-movement jumps (CMJ) and three spike jumps (SPJ). Counter-movement jump (CMJ) – a vertical jump from a standing erect position, preceded by a counter-movement of upper limbs and with lowering of the body mass centre before the take-off. Spike jump (SPJ) – a vertical jump which is performed with a 3–4 steps run-up before the take-off. There were 5 s breaks between the CMJs, and 1 min breaks between the SPJ. The jump with the highest elevation of the body's COM was chosen for statistical analysis.

Warm-up. Before vertical jump testing, subjects performed a 5 minutes of warm-up consisting of light exercise (i.e., running, circulatory of the arms, hips and trunk, squats followed by stretching exercises). Before force-velocity relationship determining the participants performed a 2-minute submaximal warm-up on a cycle ergometer (Monark 874 E, Sweden). They were instructed to cycle at 50–60 rpm and to maintain a power output of approximately 150 W.

ANOVA procedures with *post-hoc* Scheffé test were employed for comparison of mean values between the groups. The level of statistical significance was set at $p < 0.05$. Statistica™ v. 10.0 software (StatSoft, USA) was used in data analysis.

Results

Mean ($\pm SD$) values of the relative power outputs (P) and velocities (v) are presented in Table 1. Cadet judoists had a significantly smaller relative maximal power output ($11.56 \pm 1.21 W \cdot kg^{-1}$) than U23 athletes ($12.69 \pm$

Table 1. Absolute (P) and relative ($P \cdot body\ weight^{-1}$) power outputs recorded for an external force-velocity relationship (mean values $\pm SD$)

Variable	Load (% BW)	Cadet	U23	F-values	p-values
P (W)	2.5	369.1 \pm 58.5	413.0 \pm 60.6	2.017	0.179
	5.0	652.9 \pm 108.1	745.1 \pm 118.7	2.443	0.142
	7.5	835.5 \pm 131.0	968.6 \pm 171.7	2.779	0.119
	10.0	891.8 \pm 159.0	1072.4 \pm 203.9	3.576	0.081
	12.5	837.9 \pm 174.2	1047.9 \pm 184.9*	5.080	0.042
$P_{max} \cdot BW^{-1}$ ($W \cdot kg^{-1}$)	2.5	4.73 \pm 0.30	4.86 \pm 0.11	1.447	0.251
	5.0	8.37 \pm 0.76	8.76 \pm 0.28	1.828	0.199
	7.5	10.71 \pm 0.76	11.36 \pm 0.51	3.877	0.071
	10.0	11.44 \pm 1.32	12.57 \pm 0.70	4.420	0.056
	12.5	10.71 \pm 1.21	12.31 \pm 0.73*	10.003	0.008
v (rpm)	2.5	193.9 \pm 12.1	198.0 \pm 4.81	0.799	0.388
	5.0	170.1 \pm 14.3	178.1 \pm 5.7	2.151	0.166
	7.5	145.3 \pm 10.1	154.5 \pm 7.3	4.133	0.063
	10.0	116.6 \pm 13.5	128.1 \pm 7.2	4.455	0.055
	12.5	87.3 \pm 9.8	100.2 \pm 5.9*	9.883	0.008

The U23 judoists significantly different from cadet athletes (* $p < 0.05$).

Table 2. Mean values (\pm SD) of the height of rise of the body mass center (h), maximal power output (P_{\max}), relative maximal power output ($P_{\max} \cdot \text{mass}^{-1}$) during counter-movement jumps (CMJ) and spike jumps (SPJ) on a force platform

	Cadet	U23	F-values	p-values
$P_{\max\text{CMJ}}$ (W)	2370.1 \pm 572.4	3006.3 \pm 642.2	4.047	0.066
$P_{\max\text{CMJ}} \cdot \text{mass}^{-1}$ (W \cdot kg ⁻¹)	29.83 \pm 7.5	35.01 \pm 5.57	2.314	0.152
h_{CMJ} (m)	0.420 \pm 0.051	0.478 \pm 0.036*	6.546	0.024
$P_{\max\text{SPJ}}$ (W)	3403.6 \pm 542.6	4365.4 \pm 822.5*	6.905	0.021
$P_{\max\text{SPJ}} \cdot \text{mass}^{-1}$ (W \cdot kg ⁻¹)	43.22 \pm 8.49	51.70 \pm 12.78	2.215	0.161
h_{SPJ} (m)	0.516 \pm 0.07	0.560 \pm 0.054	1.919	0.189

The U23 judoists significantly different from cadet athletes (* $p < 0.05$).

0.67 W \cdot kg⁻¹; $F = 5.165$, $p = 0.041$). The optimal velocity was similar in both group (119.3 \pm 16.0 rpm and 119.6 \pm 15.5 rpm; $F = 0.001$, $p = 0.976$, respectively).

Significant age differences were found between the cadet and U23 athletes for absolute and relative power output at external load equal 12.5% BW but no significant difference was observed between the groups for values of velocity.

Table 2 presents values (mean \pm SD) of the maximal power and height of rise of the body mass center measured at SPJ and CMJ jumps performed on a force platform. Cadet judoists generated insignificantly lower absolute and relative power in CMJ and SPJ than U23 judo athletes with the exception of the absolute maximal power measured during SPJ. The age difference was observed in height of CMJ jump.

Discussion

The force-velocity relationship can be described according to Hill's equation (hyperbola) or a straight line. In our study the F - v curves were linear. This is consistent with results obtained for lower extremities by other authors [20, 21]. In the paper of Hintzy et al. [22] average v_o values amounted to 123.1 \pm 11.2 rpm and $P_{\max} \cdot \text{BM}^{-1}$ to 11.1 \pm 1.6 W \cdot kg⁻¹. Arsac et al. [23] obtained $v_o = 125 \pm 9$ rpm and $P_{\max} \cdot \text{BM}^{-1} = 11.5 \pm 1.7$ W \cdot kg⁻¹. Maximum power output recorded in this study in the cadet judoists are similar and U23 judo athletes are higher than reported for karate athletes (11.67 \pm 0.87 W \cdot kg⁻¹) [20]. The power output at external load of 7.5% BW obtained in ours study in the cadet judoists (10.71 \pm 0.76 W \cdot kg⁻¹) are lower and U23 judo athletes (11.36 \pm 0.51 W \cdot kg⁻¹) are higher than reported for cadet (15.5 \pm 0.5 years old) and junior (17.5 \pm 0.7 years old) Polish judoists (11.2 \pm 0.5 W \cdot kg⁻¹ 11.32 \pm 0.7 W \cdot kg⁻¹, respectively) by Sterkowicz et al. [5]. In our study, significant differences were founded between the cadet and U23 athletes only for absolute and relative power output at external load equal 12.5% BW and realative maximal power. No significant differences were observed between the both groups for values of velocity and optimal velocity with except of velocity at external load equal 12.5% BW. This may result from differences between age, training experience and training methods.

In paper of Detanico et al. [24] absolute and relative maximal power and height in CMJ of the judo athletes (age 20.6 \pm 1.8 years) were 2109.48 \pm 307.7 W, 27.62 \pm 11.86 W \cdot kg⁻¹, 44.76 \pm 4.51 cm, respectively. In our study cadet judoists generated insignificantly lower absolute and relative power in CMJ and SPJ than U23 judo athletes with the exception of the absolute maximal power measured during SPJ. On the other hand, the absolute and relative maximal power and height in CMJ of the Polish senior judo national team were 2819.3 \div 3122.3 W, 35.85 \div 40.34 W \cdot kg⁻¹ and 0.494 \div 0.507 m, respectively and in SPJ were 4011.5 \div 4313.8 W, 52.14 \div 55.40 W \cdot kg⁻¹ and 0.599 \div 0.605 m, respectively [25]. In comparison to the Polish senior judo national team, the jumping ability of cadet in CMJ and SPJ was considerably lower. The U23 judoist developed similar jumping abilities as elite senior judo athletes. The differences between age groups were observed only for height of CMJ and power of SPJ. CMJ and SPJ are performed differently. During CMJ the jump height and power output are assessed with the body's center of mass lowered before the jump and the leg muscles working in the stretch-shortening cycle. During SPJ also the lowered body's center of mass is used as well as the horizontal velocity of the body's center of mass during a take-off phase. Perhaps the development of the U23 significantly higher power in SPJ is the result of generating more power on cycloergometer at external load equal 12.5% BW. This is particularly important during the braking phase (eccentric work) before the take-off phase. It could be speculated that more years of judo practice of U23 compared to cadets (11.4 \pm 3.1 years vs. 6.6 \pm 2.4 years, respectively) and of strength training, could have led to specific muscle adaptations. A comparison of the body height during CMJ and SPJ also allows assessment of coordination. In elite senior judoist the difference in the height of the body mass center between CMJ and SPJ were about 0.09 \div 0.11 m [25]. In these studies the differences between height of CMJ and SPJ was 0.095 m in cadets and 0.082 m in U23 judoists and was not statistically significant between the groups. It is coherent with results by Buško and Nowak [25].

Conclusions

So far in the literature, the authors have described significant differences between subjects of different ages or cadets, juniors and seniors [11–13]. Our research has shown that U23 age class judoists were greater power output at cycloergometer tests and height of CMJ and SPJ jumps than the cadets but the differences were not statistically significant with except height of rise of the body mass center in CMJ, maximal power in SPJ and power output at external load of 12.5% BW. Force–velocity relationship and jumping test are often used to control the effects of training. Based on the characteristics of $F-v$ curve we can see in which direction follow the effects of training (the athletes improve strength or power in the part of the curve for high force and low velocity or high velocity and low force). It is important information for coach. There is not always training of maximal, external load improves maximal power because an increase of force may have large part neurologically based [26, 27]. Application of CMJ and SPJ jump in jumping tests allows, in addition to assessing the maximal power output of the lower extremities, to assess changes in neuromuscular coordination. Variables measured in CMJ jump are associated with the power development at high velocity and low force. The values measured in SPJ are associated with the generating of high force at low velocity. Differences in value of parameters CMJ and SPJ may be indicative of coordination. It seems that performance in jumping test and $F-v$ relationship is affected by the training experience. I think, the use of the both methods give better information to optimal training control.

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