# Special Judo Fitness Test and biomechanics measurements as a way to control of physical fitness in young judoists

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

**Katarzyna Boguszewska[1ABD], Dariusz Boguszewski[2ABD], Krzysztof Buśko[1,3BCDE]**

[1] Department of Anthropology, Josef Pilsudski University of Physical Education, Warsaw, Poland
[2] Department of Rehabilitation, Medical University of Warsaw, Poland
[3] Department of Biomechanics, Institute of Sport, Warsaw, Poland

**Source of support:** The study was supported by Ministry of Science and Higher Education (Grant No. AWF – DS134)

**Received:** 26 October 2010; **Accepted:** 19 November 2010; **Published online:** 30 November 2010

## Abstract

**Background and Study Aim:** The aim of this study was to compare biomechanics and special methods control of judo training process.

**Material/Methods:** The study was conducted on eight junior judoists. Special abilities were evaluated using a Special Judo Fitness Test (SJFT). Muscle torque measurements in static conditions were performed. Ten muscle groups were examined: flexors and extensors of the trunk, shoulder, elbow, hip and knee. The maximal power and height of jump were measured at BCMJ and CMJ jumps. Power-velocity relations 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.

**Results:** Mean values (±SD) index of Special Judo Fitness Test was 12.71±1.94. The values of BCMJ relative maximal power and height of jump were 44.75±8.97 W·kg$^{-1}$ and 0.526±0.071 m, respectively. The mean values of $P_{max}$ 900.8±152.9 W and $P_{max}$/mass 13.44±1.28 W·kg$^{-1}$ were corresponding to mean optimal velocity 119.3±16.0 rpm. The relative values of the muscle torque were correlated with index of SJFT, the coefficients ranging from –0.15 to –0.68. Index of SJFT correlated significantly with BCMJ values of the relative power and height of jump (r=–0.72 and –0.88, respectively). SJFT index correlated with power output and velocity in the maximal cycloergometer test, the coefficients ranging from –0.71 to 0.48.

**Conclusions:** In training process should be used biomechanics measurements, physical fitness tests and special fitness tests characteristic for own discipline as well. It will give optimal training control.

**Key words:** muscle torque • power • velocity • height of jump • Special Judo Fitness Test • Ippon-seoi-nage • Tori

**Author's address:** Dariusz Boguszewski, Medical University of Warsaw, Rehabilitation Unit, 57 Solec Str., 00-424 Warsaw, Poland; e-mail: dboguszewski@wum.edu.pl

## Background

Success in judo requires perfect physical and tactical preparation [1–3]. Judo training contains comprehensive preparation (strength, endurance and speed training), directed and special. Control of training effects is necessary part of trainers' job. Most often, the maximal muscle torques of flexors and extensors of the arms, legs and trunk in static and dynamic conditions are used for the testing purposes [4,5]. Maximal power output of legs is measured during jumps on a dynamometric platform [4,6] and/or with cycle ergometer tests [7–9].

The better part of coaches chooses methods of control which they can do in their clubs, on their trainings. Special Judo Fitness Test (SJFT) is one of these methods [10]. Standards for every factors of SJFT were created by Franchini et al. [11].

**Ippon-seoi-nage** – one-arm back-carry throw.

**Tori** – the person who applies a technique in judo training. The receiver of the technique is referred to as *uke* [25].

In the scientific literature we can find a lot of articles describe changes of biochemical, physiological, biomechanics factors of special fitness of judoists. The most of them show results of measurements in pre-competition training (PCT), in several-month training periods or some one-time measurements [1,2,4,12–17].

But there is no literature comparing kinds of methods of training process. Therefore, the aim of this study was to compare biomechanics and special methods control of judo training process.

## Material and Methods

The study was approved by the Local Ethical Committee. All participants were informed about the study aim and methodology as well as about the possibility of immediate resignation at any time of the experiment. Subjects agreed on the above conditions in written. The sample consisted of eight male judoists age 16.7±0.8 years, with body height 176.8±8.6 cm, body mass 73.7±13.8 kg and training experience 8.5±1.9 years. The measurements were performed before the preparatory period.

**The maximal muscle torque of ten groups of muscles: flexors and extensors of the elbow, shoulder, hip, knee and trunk was measured in static conditions with the use of a special device (Institute of Sport, Poland) Type SMS1 (upper extremities) and SMS2 (lower extremities and trunk)** [18]. During the measurement of the muscle torque of elbow flexors and extensors the subject was sitting, with his arm bent at a right angle and placed on the armrest, and with the trunk stabilized. The muscle torque of shoulder flexors and extensors was measured in a sitting position. The flexion angle was 70° and the extension angle 50°. The trunk was stabilized and the chest pressed against the testing station. The measurements of muscle torque of knee flexors and extensors were carried out on subjects in a sitting position. The hip and knee joints were bent at 90°. The subjects were stabilized at the level of anterior iliac spines and thighs, with the legs resting on the chest. The subjects were lying face down during the measurement of the muscle torque of hip extensors, and face up during the measurement of the muscle torque of hip flexors. The hip joint angle remained at 90° during measurement. The maximal extension of the elbow, knee and hip joints was accepted as 0°. For the shoulder joint, the positioning of the arm along the side was taken as 0°. The axis of rotation during the muscle torque measurement corresponded to the axis of rotation of the torque meter. The right arm and left arm muscles were measured separately, always in the flexion–extension sequence. Each subject was supposed to achieve the maximal power output during measurement. To analysis was used results of sum of the muscle torque of right (RUE – flexors and extensors of the elbow and shoulder) and left (LUE – flexors and extensors of the elbow and shoulder) upper extremities, sum of muscle torque of both upper extremities (SUE), sum of the muscle torque right (RLE – flexors and extensors of the hip and knee) and left (LLE – flexors and extensors of the hip and knee) lower extremities, sum of the both lower extremities (SLE), sum of the muscle torque of the trunk (ST – flexors and extensors of the trunk) and sum of ten muscle groups (TOTAL – flexors and extensors of the elbow, shoulder, hip, knee for right and left side separately and trunk). Absolute results was measured in [N·m] and relative results in [$N \cdot m \cdot kg^{-1}$].

**The power output of lower extremities and the height of rise of the body mass center during vertical jumps** were measured on a dynamometric platform with a Kistler amplifier Type 9281A (Switzerland) for counter-movement jumps (CMJ) and bounce counter-movement jumps (BCMJ). The amplifier was connected to a PC via an a/d converter. The MVJ v. 3.4. software package 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 [W], relative maximal power [$W \cdot kg^{-1}$] and maximal height ($h$) of rise of the center of body mass (COM) [m] were calculated from the registered reactive force of the platform [4]. Each subject performed six vertical jumps with maximal force on the dynamometric platform: three counter-movement jumps (CMJ) and three bounce counter-movement jumps (BCMJ). There were 5 s breaks between the CMJs, and 1 min breaks between the BCMJ. The jump with the highest elevation of the body's COM was chosen for statistical analysis.

**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 player 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 [19]. 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 [19]. The maximal power output and optimal pedaling velocity were computed from individual equations of the second degree polynomial describing the $P$–$v$ relationship [19]. 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·kg$^{-1}$] respectively.

**Special abilities were evaluated using a Special Judo Fitness Test (SJFT).** This test is divided in three periods (A=15 s; B and C=30 s) with 10 s intervals among them. During each period the athlete (*tori*) been evaluated throws two partners (*uke* A and *uke* B; standing in front by 6 m) as many time as possible using the *ippon-seoi-nage* technique (Figure 1). Both *uke* A and B should have a similar height and weight from the *tori*. Just after and one minute after the test heart rate is HR (type of heart rate monitor Polar) measured. The throws are added and the following index is calculated [11]:

$$\text{Index} = \frac{\text{final HR [bpm]} + \text{HR 1 min. after the test [bpm]}}{\text{Number of throws}}$$

bpm – bites per minutes

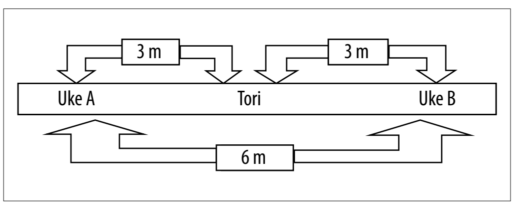


**Figure 1.** Special Judo Fitness Test representation [10].

Relationships between the muscle torques, power output, velocity, height of rise of the body mass center and the index of Special Judo Fitness Test were assessed by calculating the Pearson's linear correlation coefficients. The level of statistical significance was set at $p<0.05$. All calculations were made with the aid of Statistica software package [20].

## Results

The mean values (±SD) of sum of the absolute muscle torque of right (RUE) and left (LUE) upper extremities, sum of the absolute muscle torque of both upper extremities (SUE), sum of the absolute muscle torque right (RLE) and left (LLE) lower extremities, sum of the absolute muscle torque of both lower extremities (SLE), sum of the absolute muscle torque of the trunk (ST) and sum of ten muscle groups (TOTAL) were 271.0±53.7 N·m, 267.3±62.0 N·m, 538.3±113.5 N·m, 1075.1±132.7 N·m, 1048.4±134.5 N·m, 2123.5±260.3 N·m, 744.9±144.7 N·m, and 3406.6±474.6 N·m, respectively. The relative values of RUE, LUE, SUE, RLE, LLE, SLE, ST and TOTAL were 3.61±0.73 N·m·kg$^{-1}$, 3.55±0.83 N·m·kg$^{-1}$, 7.16±1.53 N·m·kg$^{-1}$, 14.40±2.26 N·m·kg$^{-1}$, 13.97±1.57 N·m·kg$^{-1}$, 28.37±3.77 N·m·kg$^{-1}$, 9.99±2.35 N·m·kg$^{-1}$, and 45.52±7.14 N·m·kg$^{-1}$, respectively.

The mean values of CMJ maximal power, relative maximal power and height of rise of the body mass centre were 2381.9±530.9 W, 31.02±7,78 W·kg$^{-1}$ and 0.433±0.059 m, respectively. The values of BCMJ maximal power, relative maximal power and height of rise of the center of body mass were 3412.3±503.0 W, 44.75±8.97 W·kg$^{-1}$ and 0.526±0.071 m, respectively. Mean values (±SD) of the absolute and relative power output recorded for external force-velocity relationships are presented in Table 1. The mean values of $P_{max}$ 900.8±152.9 W and $P_{max}$/mass 13.44±1.28 W·kg$^{-1}$ were corresponding to mean optimal velocity ($v_o$) 119.3±16.0 rpm.

Mean values (±SD) index of Special Judo Fitness Test (SJFT) was 12.71±1.94 (Table 2). Lower index in SJFT is interpreted as better results.

The relative values of RUE, LUE, SUE, RLE, LLE, SLE, ST and TOTAL were correlated with index of SJFT –0.40, –0.15, –0.27, –0.61, –0.68, –0.65, –0.39 and –0.53, respectively. Index of SJFT correlated significantly (p<0.05) with BCMJ values of the relative power and height of rise of the center of body mass (r=–0.72 and –0.88, respectively). The CMJ values of the relative power and height of rise of the center of body mass correlated with SJFT index (r=–0.61 and –0.60). SJFT index correlated with power output or velocity in the maximal cycloergometer test, the coefficients ranging from –0.71 to 0.48 (Table 3).

## Discussion

Evaluate the level of the physical characteristics of an athlete is one of the most important issues of training process. Professional literature includes a number of works on exercise physiology of male and female judoists [1,2,12–14,21], but there are very few studies concerned with judoists' biomechanics [4,15].

**Table 1.** Absolute and relative power output (*P*) and velocity (*v*) recorded for an external force-velocity relationship (mean values ±SD, n=7).

| Load [%BW] | P [W] | P/mass [W·kg$^{-1}$] | v [rpm] |
|---|---|---|---|
| 2.5 | 369.1±58.5 | 4.73±0.30 | 193.9±12.1 |
| 5.0 | 652.9±108.1 | 8.37±0.76 | 170.1±14.3 |
| 7.5 | 835.5±131.0 | 10.71±0.76 | 145.3±10.1 |
| 10.0 | 891.8±159.0 | 11.44±1.32 | 116.6±13.5 |
| 12.5 | 837.9±174.2 | 10.71±1.21 | 87.27±9.8 |

Mean values (±SD) of variables measured in the Special Judo Fitness Test (SJFT) are shown in Table 2.

**Table 2.** Mean variables of Special Judo Fitness Test (n=8).

| Statistics | Total of throws | HR after (bpm) | HR 1 min after (bpm) | Index |
|---|---|---|---|---|
| Average ±SD | 25±3.6 | 187±19.9 | 129±10.9 | 12.71±1.94 |

**Table 3.** Correlation coefficient between index of Special Judo Fitness Test and the absolute and relative power output (P), velocity (v) in the maximal cycloergometer test (n=7); (correlated significantly p<0.05).

| Load [%BW] | P [W] | P/mass [W·kg$^{-1}$] | v [rpm] |
|---|---|---|---|
| 2.5 | 0.47 | –0.71 | –0.63 |
| 5.0 | 0.36 | –0.66 | –0.60 |
| 7.5 | 0.45 | –0.69 | –0.71 |
| 10.0 | 0.31 | –0.56 | –0.56 |
| 12.5 | 0.48 | –0.14 | –0.15 |
| Max | 0.37 | –0.53 | –0.04 |

Trzaskoma [17] showed that after three years of training, the percent contribution of the maximal torque of arms in the sum of the muscle torque of all muscle groups increased by 1.7%, whereas the relative value of the sum of the maximal muscle torque of the arm, trunk and the sum of the muscle torque of ten muscle groups decreased significantly by 5.9%, 7.5% and 4.6%, respectively. In two-year training cycle the muscle torque value increased by about 3%.

An evaluation of the strength of lower limbs of female and male judo contestants of the national team in the period of direct competition cycle preparation was performed by Buśko and Nowak [2]. In comparison to the Polish senior judo national team, the relative results of maximal muscle strength moment, relative and absolute strength as well as jumping ability, both in the case of a counter movement jump, and bound counter movement jump, of contestants from junior groups (examined for the purposes of this study) were considerably lower. The best Polish judo contestants developed the strength of lower limbs at the level of 3122.3 W in a CMJ examination and 4313.8 W, and junior and younger junior – correspondingly 2381.9 W and 3412.3 W. A similar tendency was observed in the case of relative strength. Seniors developed strength at the level of 40.34 W·kg$^{-1}$ in a counter movement jump and 55.40 W·kg$^{-1}$ in a bound counter movement jump, however junior contestants developed relative strength at the level of 31.02 W·kg$^{-1}$ and 44.75 W·kg$^{-1}$ [4].

On the basis of a SJFT Index classification standard developed by Franchini and co. [11], judo contestants were characterized by good and outstanding special fitness. Average value of the SJFT Index (12.71) acquired by judokas in our examinations was similar to the results acquired by the best Polish and Brazilian judo contestants [16]. Polish junior judo contestants were characterized by better body restoration after physical effort (187 bpm directly after and 129 bpm after 1 min. following the physical effort) than the best Brazilian senior judo contestants (correspondingly: 179 and 181 bpm directly after and 163 and 150 bpm after 1 min. following physical effort). With respect to the number of throws executed during training, junior contestants (25) were weaker than senior contestants (27) and Brazilians (28) [1,16].

In a setting of the results of bio-mechanic parameters with the SJFT Index, a negative correlation was noted. The biggest correlation was observed during the development of relative strength of lower limbs during a counter movement jump and bound counter movement jump, as well as during tests on cyclometer and in relation to maximal lower limb muscle strength moments. A similar tendency was noted in research by Sterkowicz and co. [16].

Physical fitness tests are an indispensable element of the training process. The sports result comprises numerous factors, specific for a particular discipline. The usefulness of chosen endurance tests was confirmed by research by Lech et al. [22,23] conducted on junior judo contestants. It has been proven, however, that superiority over the opponent with respect to physical fitness is not the factor deciding on victory in direct round [24]. In the course of further research, it seems justified to compare chosen results of bio-metric measurements with the results of special tests and with the effectiveness of sports fights.

## Conclusions

1. In training process should be used biomechanics measurements, physical fitness tests and special fitness tests characteristic for optimal training control.

2. Future research should focus the development of classificatory table for biomechanics parameters.

## References:


1. Franchini E, Takito MY, De Moraes Bertuzzi RC: Morphological, physiological and technical variables in high-level college judoists. Archives of Budo, 2005; 1: 1–7
2. Franchini E, Takito MY, Kiss MA, Sterkowicz S: Physical fitness and anthropometrical differences between elite and non-elite judo players. Biol Sport, 2005; 22(4): 315–28
3. Thomas SG, Cox MH, LeGal YM et al: Physiological profiles of the Canadian National Judo Team. Can J Sport Sci, 1989, 14(3): 142–47
4. Buśko K, Nowak A: Changes of maximal muscle torque and maximal power output of lower extremities in male judoists during training. Human Movement, 2008; 9(2): 111–15
5. Janiak J, Wit A, Stupnicki R: Static muscle force in athletes practising rowing. Biol Sport, 1993; 10: 29–34
6. Buśko K, Rychlik R: Changes of the maximal muscle torque in women training Power Yoga (Astanga Vinyasa). Human Movement, 2006, 7(2): 168–77
7. Buśko K: Changes of force-velocity and power-velocity relationships after training performed on cycle ergometer. Biol Sport, 2006; 23(1): 17–32
8. Buśko K: Changes of power-velocity relationship in volleyball players during the one years training. Human Movement, 2009; 10(2): 149–52
9. Norkowski H, Buśko K: Changes in power output under the influence of sprint training in handball players. Acta Bioeng Biomech, 2004; 6(1): 31–40
10. Sterkowicz S: Test specjalnej sprawności ruchowej w judo. Antropomotoryka, 1995; 12: 29–44 [in Polish]
11. Franchini E, Del Vecchio FB, Sterkowicz S: A special judo fitness test classificatory table. Archives of Budo, 2009; 5: 127–29
12. Borkowski L, Faff J, Starczewska-Czapowska J: Physiological and performance responses to overtraining in elite judo athletes. Med Sci Sports Exerc, 2001; 22: 816–24
13. Callister R, Callister RJ, Staron RS et al: Physiological characteristics of elite judo athletes. Int J Sports Med, 1991; 12(2): 196–203. DOI: 10.1055/s-2007-1024667
14. Degoutte F, Jouanel P, Filaire E: Energy demands during a judo match and recovery. Br J Sports Med, 2003, 37: 245–49. DOI: 10.1136/bjsm.37.3.245
15. Fagerlund R, Hakkinen K: Strength profile of Finnish judoists – measurement and evaluation. Biol Sport, 1991; 8(3): 143–49
16. Sterkowicz S, Zuchowicz A, Kubica R: Levels of anaerobic and aerobic capacity indices and results for the special judo fitness test in judo competitors. Journal of Human Kinetics, 1999; 2: 115–35
17. Trzaskoma Z: Maximal muscle strength and maximal power of female and male practising sport. Studia i Monografie 94, AWF, Warszawa, 2003 [in Polish]
18. Jaszczuk J, Buczek M, Karpiłowski B et al: Set-up for force measurements in static conditions. Biol Sport, 1987; 4(1–2): 41–55
19. Buśko K: Economical and optimal pedaling velocity characteristics during maximal and submaximal efforts on cycloergometer. Biol Sport, 2007; 24(3): 209–26
20. StatSoft, Inc. (2007). STATISTICA (data analysis software system), version 8.0. *www.statsoft.com*
21. Callister R, Callister RJ, Fleck SJ, Dudley GA: Physiological and performance responses to overtraining in elite judo athletes. Med Sci Sports Exerc, 1990; 22(6): 816–24
22. Lech G, Pałka T, Sterkowicz S et al: Effect of physical capacity on the course of fight and level of sports performance in cadet judokas. Archives of Budo, 2010a; 6(2): 123–28
23. Lech G, Tyka A, Pałka T, Krawczyk R: Effect of physical endurance on fighting and the level of sports performance in junior judokas. Archives of Budo, 2010b; 6(1): 1–6
24. Kalina RM, Chodała A, Dadeło S et al: Empirical basis for predicting success in combat sports and self-defence. Journal of Kinesiology, 2005; 37: 64–73
25. Budō: The Martial Ways of Japan. Nippon Budokan Foundation, 2009