



CHANGES OF MAXIMAL MUSCLE TORQUE AND MAXIMAL POWER OUTPUT OF LOWER EXTREMITIES IN MALE JUDOISTS DURING TRAINING

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ABSTRACT

Purpose. The aim of the study was to follow changes of the maximal muscle torque and maximal power output of lower extremities in male judoists during pre-competition training (PCT). The original hypothesis assumed that different training loads would cause changes of the maximal muscle torque and maximal power output of legs in male judoists during pre-competition training, but not changes of the topography of the maximal muscle torque in all muscle groups. **Basic procedures.** The study sample consisted of five male judoists from the Polish National Team. Muscle torque measurements in static conditions were performed shortly before PCT (I), after the strength training mesocycle (II) and immediately after PCT (III). Ten muscle groups were examined: flexors and extensors of the trunk, shoulder, elbow, hip and knee. The maximal power output of legs was measured on a dynamometric platform during counter-movement jumps (CMJ) and bounce counter-movement jumps (BCMJ). **Main findings.** The sums of the muscle torque of both arms and the trunk were changed insignificantly during pre-competition training (PCT). The sum of muscle torque of the right and left lower extremities increased significantly between the measurements I and III. The muscle percent topography of muscle groups also showed significant changes. Maximal power output of lower extremities measured during CMJ decreased significantly, but increased during BCMJ. **Conclusion.** PCT caused changes of the maximal muscle torque of lower extremities, but the muscle topography of the muscle groups revealed significant changes, too. The maximal power output of lower extremities measured during CMJ decreased.

Key words: bounce counter-movement jump (BCMJ), counter-movement jump (CMJ), judo, muscle percent topography, muscle torque, power output

Introduction

Changes of the maximal muscle torque and power output of legs are indicative of the athlete's training level and effects of applied training loads. 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 [1, 2]. The muscle torque can also be represented as the percent contribution of particular muscle groups [2–4]. Maximal power output of legs is measured during jumps on a dynamometric platform [5, 6] and/or with cycle ergometer tests [7–9].

Success in judo requires perfect physical and tactical preparation [10, 11]. The planning of judo training should not only concern the applied training loads, but

it should also focus on the practitioners' physical abilities. 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 [12].

The aim of the study was to examine changes of the maximal muscle torque and maximal power output of judoists' legs during pre-competition training (PCT). The original hypothesis was that the different training loads would cause changes of the maximal muscle torque and maximal power output of legs in male judoists during pre-competition training, but not changes of the topography of the maximal muscle torque of all muscle groups.

Material and methods

The study was approved by the Research Ethics Committee. The study sample consisted of five judoists

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of the Polish National Team, aged 24.7 ± 2.1 years. The subjects' mean body height was 174.8 ± 5.9 cm, and body weight 76.0 ± 6.0 kg (I), 76.8 ± 6.2 kg (II) and 76.3 ± 7.3 kg (III). The subjects' body weight did not change significantly. Three measurements were carried out: before the PCT (I), immediately after the strength training mesocycle (II), immediately after PCT (III).

Measurement of the maximal muscle torque in static conditions. 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 [3]. 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.

The power output of lower extremities and the height of elevation of the center of mass during vertical jumps were measured on a dynamometric platform with a Kistler amplifier 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 maxi-

mal power and maximal height of the center of mass elevation (h) were calculated from the registered reactive force of the platform [5]. 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 center of mass was chosen for statistical analysis.

All measurements were performed in the morning; the subjects were informed about the aims and methodology of the tests prior to the measurements.

The results were statistically processed with the use of analysis of variance (ANOVA) for repeated measures. The statistical significance of the differences between the mean values was assessed with the post hoc least significant difference test (LSD test). The level of statistical significance was set at $p < 0.05$. All calculations were made with the aid of Statistica (v. 5.5, StatSoft) software package.

Results

Tab. 1 presents the maximal muscle torque values (M_m) achieved by the judoists under study. No significant changes were observed in the sum of the maximal torque of both arms, sum of the maximal muscle torque of the right arm and sum of the maximal muscle torque of the left arm. The sums of the maximal muscle torque of the right leg and the left leg increased between the measurements I and II by 5.8% and 2.3%, respectively; and increased significantly between the measurements I and III by 20.5% and 20.7%, respectively. The sum of the maximal muscle torque of the trunk remained unchanged between the measurements I and II (0.4%), and then decreased by 7.7%. Tab. 2 presents the maximal muscle torque values as the mean percent contributions of particular muscle groups. A significant difference of the percent topography of the sum of the maximal muscle torque of the left arm, right leg, left leg and trunk between the measurements I and III was noted. The CMJ and BCMJ results are presented in Tab. 3. The maximal power output of the legs during counter-movement jumps decreased significantly between the measurements I and II by 9.7%, but the difference was non-significant between the measurements I and III (decrease by 6.8%). The changes in the maximal power output during bounce counter-movement jumps and

jump height measured during CMJ and BCMJ were statistically non-significant.

Discussion

Professional literature includes a number of works on exercise physiology of male and female judoists [13–

Table 1. Changes of mean values (\pm SD) of the sums of the maximal muscle torque ($\text{N}\cdot\text{m}\cdot\text{kg}^{-1}$) of the right (R) and left (L) upper extremity (SUE), lower extremity (SLE), trunk (ST), both upper extremities (SUEE), both lower extremities (SLEE) and all ten muscle groups (TOTAL) during PCT

Vari- ables	measurement I	measurement II	measurement III
SRUE	4.91 \pm 0.82	5.06 \pm 0.68	5.26 \pm 0.35
SLUE	4.87 \pm 0.49	5.06 \pm 0.48	4.62 \pm 0.17
SRLE	14.84 \pm 0.20	15.71 \pm 1.34	17.87 \pm 1.15 ^{a, b}
SLLE	14.74 \pm 1.70	15.95 \pm 1.22	17.64 \pm 1.41 ^a
SUEE	9.78 \pm 1.26	10.12 \pm 1.06	9.88 \pm 0.48
SLEE	29.58 \pm 1.58	31.66 \pm 1.64	35.52 \pm 2.35 ^a
ST	12.02 \pm 0.56	11.97 \pm 1.15	11.09 \pm 1.18
TOTAL	51.38 \pm 1.83	53.75 \pm 3.41	56.49 \pm 2.68 ^a

^a significantly different from the measurement I,

^b significantly different from the measurement II

Table 2. Changes of mean values (\pm SD) of topography of the maximal muscle torque (%) of the right (R) and the left (L) upper extremity (SUE), lower extremity (SLE) and trunk (ST) during the PCT

Vari- ables	measurement I	measurement II	measurement III
SRUE	9.55 \pm 1.52	9.41 \pm 1.05	9.32 \pm 0.76
SLUE	9.49 \pm 0.96	9.41 \pm 0.60	8.20 \pm 0.58 ^{ab}
SRLE	28.91 \pm 1.14	29.21 \pm 1.48	31.64 \pm 1.17 ^{ab}
SLLE	28.66 \pm 2.72	29.73 \pm 2.26	31.20 \pm 1.34 ^a
ST	23.40 \pm 0.85	22.24 \pm 0.89	19.64 \pm 1.97 ^{ab}

^a significantly different from the measurement I,

^b significantly different from the measurement II

Table 3. Changes of mean values (\pm SD) of the height of elevation of the body's center of mass (h), maximal power output (P_{\max}) during counter-movement jumps and bounce counter-movement jumps on a dynamometric platform during PCT

Variables	measurement I	measurement II	measurement III
$P_{\max\text{CMJ}}$ (W)	3122.300 \pm 753.200	2819.300 \pm 768.000 ^a	2911.300 \pm 798.100
$P_{\max\text{CMJ}}/\text{mass}$ (W/kg)	40.340 \pm 6.460	35.850 \pm 6.790 ^a	37.520 \pm 7.350
h_{CMJ} (m)	0.502 \pm 0.048	0.494 \pm 0.052	0.507 \pm 0.055
$P_{\max\text{BCMJ}}$ (W)	4113.000 \pm 1214.20	4313.800 \pm 832.500	4011.500 \pm 812.200
$P_{\max\text{BCMJ}}/\text{mass}$ (W/kg)	52.990 \pm 11.710	55.400 \pm 9.300	52.140 \pm 9.200
h_{BCMJ} (m)	0.605 \pm 0.079	0.599 \pm 0.056	0.599 \pm 0.053

^a significantly different from the measurement I

15], but there are very few studies concerned with judoists' biomechanics [1, 16].

The aim of pre-competition training (PCT) is to make athletes achieve the highest level of physical characteristics and prepare them for the main competition of the season. Therefore at different PCT stages changes of physical characteristics of athletes should be noted. The present study revealed a non-significant increase of the sum of the maximal muscle torque (M_m) of the upper and lower extremities; a decrease in the sum of the maximal muscle torque of the trunk between the measurement before PCT (I) and after the strength training mesocycle (II); a significant increase in the sum of the maximal muscle torque of the right leg and left leg; and a decrease in the sum of the maximal muscle torque of the trunk and the left arm immediately after PCT (III). Trzaskoma [2] 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 a two-year training cycle the muscle torque value increased by about 3%.

Literature lacks explicit and unambiguous conclusions about changes of power output during different types of jumps performed after different kinds of training [17–19]. Kubo et al. [18] noted no changes in the height of the body's center of mass during a CMJ (0.3%) after a 12-week isometric strength training. In Harris et al. [17] strength training did not increase jump height measured during CMJ, whereas high "force" training (strength training with 30% of maximal isometric force) increased jump height during a CMJ and a standing long jump. Prouteau et al. [19] noted a significant decrease in jump height measured with the Sargent test,

from 44 to 40 cm, after a six-month training, and to 36 cm after further 3-week training during the season. The present study did not reveal any significant changes in the height of the body's center of mass during CMJ and BCMJ. However, the power output during BCMJ saw a non-significant increase between the measurements I and II, and then it decreased. In the case of power output during CMJ a significant decrease of power between the measurements I and II, and a non-significant decrease of power between the measurements I and III were noted. We are not able to provide any sufficient explanation of these results. CMJ and BCMJ 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 extension-flexion sequence. During BCMJ 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 run-up. A comparison of the body height during CMJ and BCMJ also allows assessment of coordination of the run-up and bounce stages of the jump. In volleyball players the difference in the height of the body's center of mass between CMJ and BCMJ was about 0.13 m, and in power output 18.99 W/kg. In the judoists the difference between the jumps was 0.10 m during the measurement I, 0.11 m during the measurement II and 0.09 m during the measurement III. According to Häkkinen [12] long-lasting, intensive training should mainly affect the maximal power output, whereas the increase in the explosive force should be relatively lower. This might serve as an explanation for the increase in the maximal muscle torque of the legs, a non-significant decrease in power output during the vertical jumps, and lack of changes in jump height observed in the present study.

Conclusions

The obtained results confirm the research hypothesis only partially:

1 The following changes were observed in the judoists under study during the pre-competition training:

- Decreases in the sums of the maximal muscle torque of the trunk and of the left leg between the measurements at the beginning (I) and immediately after (III) PCT.

- Increases in the sums of the maximal muscle torque of the right leg and the left leg (significant) and of the right arm (non-significant).

2. The topography of the muscle torque was significantly changed, with the exception of the percentage contribution of the sum of the maximal muscle torque of the right arm.

3. The jump height, measured with the height of the body's center of mass as well as power output during BCMJ remained unchanged during pre-competition training. During CMJ no changes in the jump height were observed as well as a decrease in the maximal power output.

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