Changes in the muscular outputs of young judoists during resistance exercises performed on unstable equipment: A case study

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B Data Collection
C Statistical Analysis
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Milovan Bratic[1ABCDE], Dragan Radovanovic[1ABCDE], Aleksandar Ignjatovic[2ABCD], Ivana Bojic[1BD], Nenad Stojiljkovic[1BD]

[1] Faculty of Sport and Physical Education, University of Nis, Nis, Serbia
[2] Faculty of Pedagogy Jagodina, University of Kragujevac, Kragujevac, Serbia

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Abstract

Background and Study Aim: Resistance exercises under unstable conditions have gained popularity among athletes. The aim of the study was to investigate the changes in muscular outputs (peak power and velocity of movement) during bench presses and squats under unstable conditions in comparison to the outputs under stable conditions.

Material/Methods: A total of 20 participants, divided into two groups, took part in the study. The first group consisted of 9 top-level young male judoists, while the second group consisted of 11 students. All of the exercises were performed once 70% of one-repetition maximum (1RM) was determined.

Results: The analysis showed a significant reduction in muscular outputs during squats under unstable conditions (the BOSU ball) in comparison to stable conditions for the group of judoists. However, there was no significant reduction in muscular outputs during the bench presses under unstable conditions (the Swiss ball) compared to the stable flat bench. For the group of students, the analysis showed a significant reduction in muscular outputs during the bench press under unstable conditions when compared to the stable flat bench. In addition, for this group the muscular outputs were significantly lower during squats under unstable in comparison to stable conditions.

Conclusions: The bench press as a resistance exercise performed on a Swiss ball with reduced training load cannot be recommended as an effective training model for judoists. Nevertheless, the squat with reduced training load under unstable conditions provided sufficient challenges to the neuromuscular system and could be incorporated into training programs.

Key words: instability • resistance training • power • bench press • squat

Author's address: Milovan Bratic, Department of Combat Sports, Faculty of Sport and Physical Education, University of Nis, Carnojevica 10A, 18000 Nis, Serbia; e-mail: bratic_milovan@yahoo.com

Background

The use of instability devices and exercises to train core musculature has become a feature of many training centers and programs. Resistance training exercises under unstable conditions, such as those during the use of a Swiss ball and/or BOSU ball, have gained popularity among the population of athletes [1,2]. Whether instability resistance training is more or less effective than traditional ground-based resistance training has not been fully resolved. Greater instability should challenge the neuromuscular system to a greater extent than stable conditions, possibly enhancing strength gains attributed to neural adaptations [3]. Nevertheless, the possibility of reduced training load associated with unstable exercises may be compensated by high muscle activation and internal muscle tension

Instability – lack of steadiness or stability.

Resistance training – training designed to increase power, strength and muscular endurance.

providing similar training stresses [4]. Athletes are generally expected to have developed advanced motor performance skills compared to those individuals who are not involved in regular sport activities. Judo is characterized by short duration, high-intensity, intermittent exercises followed by a period of constant pulling, pushing, lifting, grappling and gripping movements in preparation for the next explosive effort [5]. Because judo as a sport provides balance challenges, the practice of specific activities may nullify the need for specialized instability devices. There are many articles in the literature that promote core training programs and exercises for performance enhancement without providing a strong scientific rationale of their effectiveness, especially in the sporting sector. To determine whether performing strength training under unstable conditions is beneficial to the improvement of athletic performance, the response of the limb musculature to unstable conditions during dynamic movement must also be examined [6]. The aim of the study was to investigate the changes in muscular outputs (peak power and velocity of movement) during bench presses and squats under unstable conditions in comparison to stable conditions, in the case of judoists and students of the Faculty of Sport. Previous similar research has determined that judokas have a well-developed aerobic capacity in comparison to the students of the Faculty of Sport and Physical Education, which is most likely the effect of a combination of training and competition experience [7]. For the purpose of this study, the dynamic bench press and squats were used, since they are some of the most widely performed exercises by athletes. The results of this study should provide an answer to the question of the effectiveness of including resistance training exercises under unstable conditions into the training programs for judoists.

Power – the rate of performing work; the product of force and velocity. The rate of transformation of metabolic potential energy to work or heat (SI unit: Watt).

Squat – a resistance-training exercise in which one squats and stands while holding a weighted barbell supported by the back of the shoulders.

Bench press – a relatively simple resistance-training exercise of the upper body a in which a person lies on a bench and press weights upward. It is usually performed with a barbell.

Material and Methods

The sample consisted of 20 male participants, divided in two groups. The first group consisted of 9 high-level young male judoists (age 21±1.3 years, height 175.2±6.9 cm, weight 73.8±7.6 kg), including winners and medal recipients at the national championships of Serbia and championships of the Balkan region, with sports careers spanning several years (average sport experience 10±2.6 years). All of them were members of judo club "Kinezis" from the city of Nis, and took part in regular judo training programs at the time of study. During their long training history, they had experience with various resistance training involving exercises such as the bench press and squats, among many others. However, they had no previous experience with these types of instability resistance exercises.

The second group consisted of 11 male students of the Faculty of Sport and Physical Education in Nis (age 21±0.9 years, height 177.4±6.2 cm, weight 74.9±6.8 kg). At the time of the study, none of the university students was a professional athlete. The level of their physical fitness reflected their curriculum, which included various forms of practice, as well as their individual recreational practices (including additional daily physical activities for at least one hour). None of the participants from this group had taken part in organized and programmed resistance training in the past year.

All of the participants had volunteered to take part in the study. They were informed regarding the main purpose of the study, procedures, and the experimental risks, and they all signed an informed consent document prior to the study. The procedures presented were in accordance with the ethical standards on human experimentation. Standard medical screening was performed before the study. None of the participants showed any evidence of recent injury in their anamnesis or clinical report.

Familiarization

Prior to the study, the participants were exposed to two familiarization sessions. Before data collection, the participants were given an orientation session where they were instructed on the proper technique of both exercises, in particular on unstable surfaces. Emphasis was placed on achieving a knee angle of 90° during the squats. The participants had another familiarization session specifically designed for the testing procedures. Both the judoists and university students had the same number of familiarization session before the testing procedures, and were instructed not to engage in exhausting exercise for a period of 48 hours prior to testing. They were warned to refrain from eating or drinking energy or caffeine drinks for two hours prior to the testing. The participants were allowed to drink non-caffeinated liquids ad libitum before testing.

Study setting

All of the testing sessions took place in a gymnasium. Prior to testing, the participants warmed up for approximately 10–15 minutes of submaximal intensity aerobic activity on stationary bikes and/or step machines and short bouts of dynamic muscle stretching.

1RM Testing

The participants underwent a one-repetition maximum (1RM) test on a stable surface. Prior to each 1RM test, two warm-up sets were performed: first with 8 repetitions at approximately 50% of 1RM, and then with 4 repetitions at approximately 70% 1RM. Next, single attempts with increasingly heavier resistance of at least 2.5 kg were performed until each participant reached

Table 1. Mean (SD) values of peak power and velocity outputs between stable and unstable conditions for the group of judoists (n=9).

Condition/variables (unit)	Power (W)	Velocity ($cm \cdot s^{-1}$)
Stable condition (flat bench)	413.89±64.97	59.18±7.21
Unstable condition (Swiss ball)	393.44±76.85	60.26±11.11
Stable condition (floor)	874.78±77.02	100.56±8.08
Unstable condition (BOSU ball)	599.11±133.57*	81.67±8.53*

*A significant difference ($p<0.001$) compared to the corresponding value under stable conditions.

the greatest weight that he could lift once with correct technique. A 3-minute rest period was given between each lift. The 1RM was achieved within 3–6 attempts. For safety, two spotters were present at all times. Correct bench press technique involved lowering the bar in a controlled manner until it lightly touched the chest, after which the bar was lifted back to the start position with elbows fully extended. Careful attention was paid to ensuring the bar did not bounce off the chest, especially on the exercise ball. No compensatory motion was allowed during the bench press movement. Barbell squats on a stable surface were performed from full extension to a knee angle of 90° while the participant held the barbell on his back. The participants were monitored in order to ensure that they lifted the barbell without significant deviation from a line perpendicular to the floor. The tempo of each 1RM attempt was not controlled so that as long as good technique was adhered to, the participants could take as long as required to complete the lift.

Testing under stable and unstable conditions

All of the exercises were performed with a previously established 70% 1RM. Although 80% of 1RM is usually required to improve muscle strength [8], from our experience the use of more than 70% of 1RM under unstable conditions may be very dangerous and may lead to anxiety about falling. Under such conditions the validity of the measurements could be compromised. Stable conditions were enabled by a flat bench. The participant's feet were placed wide enough to stabilize the body. The knee flexion angle was fixed at approximately 90° during the measurement. The participants were not allowed to lift their shoulders or buttocks from the bench or their feet from the floor. The unstable conditions were enabled by a Swiss ball with a diameter of 65 cm placed to support only the upper back, not the cervical area or head and with the participants' feet placed on the floor. Complete inflation of the ball was confirmed before each experiment. Barbell squats under stable conditions (floor of the gymnasium) and an unstable BOSU ball (BOSU; Fitness Quest, Canton, OH, USA) were performed from full extension to a knee angle of 90° while the participant held the barbell on his back. For safety reasons, two testers spotted the participants by standing on each side during the lift, and one tester stood behind the participants to impede a possible fall. In addition, the tester confirmed the consistency in the quality of the bench press and squat technique throughout the testing. If the attempt did not follow the instructions, the participant was asked to make another attempt for additional data collection.

Muscular outputs (peak power and velocity of movement) for each repetition were measured by means of the Fitrodyne dynamometer (Fitronic, Bratislava, Slovakia) according to the suggested protocol. The validity and reliability of the device was confirmed by Jennings et al. [9], and the device was also used in similar studies [10,11]. During each of the sessions, the participants were instructed to accelerate the barbell as fast as possible during the entire range of motion, during which the peak power and velocity of movement were measured by means of a computer-interfaced Fitrodyne attached to the barbell via a tether. All of the data were computed, based on Newton's second law, by using the appropriate software (Fitronic, Bratislava, Slovakia) in addition to the dynamometer.

Statistical analyses

The Kolmogorov-Smirnov test of normality was performed on all the variables. All of the data were normally distributed, and a paired t-test was used to compare peak power and velocity of movement during the bench press and squats between the stable and unstable conditions for both groups of participants. Reduction rates of peak power and velocity of movement were calculated by using the following equitation: reduction rates (%) = [1 – (muscular output under unstable conditions / muscular output under stable conditions)] ×100. An independent sample t-test was used to compare reduction rates of peak power and velocity of movement between groups. The data were described as means ± standard deviation (SD). Statistical significance was set at $p<0.05$ for all of the statistical analyses.

Results

There were no significant anthropometric or age differences between the groups. An analysis of the obtained

Table 2. Mean (SD) values of peak power and velocity outputs between stable and unstable conditions for the group of students (n=11).

Condition/variables (unit)	Power (W)	Velocity (cm·s^{-1})
Stable condition (flat bench)	392.64±2748	65.09±14.44
Unstable condition (Swiss ball)	331.73±34.27 *	57.69±10.43 *
Stable condition (floor)	674.82±78.52	107.45±13.25
Unstable condition (BOSU ball)	397.27±59.04*	71.09±5.11*

* A significant difference (p<0.001) compared to the corresponding value under stable conditions.

data for the group of judoists using a parametric t-test for paired samples showed a statistically significant reduction of muscular outputs (peak power and velocity) during squats under unstable conditions (the BOSU ball). There was no statistically significant reduction of peak power (p=0.11) and velocity (p=0.68) outputs during the bench press under unstable conditions (the Swiss ball) in comparison to the stable flat bench (Table 1).

The statistical analysis of the obtained data for the group of students showed a statistically significant reduction of peak power and velocity of movement during the bench press under unstable conditions (the Swiss ball) in comparison to the stable flat bench. In addition, in this group muscular outputs (peak power and velocity) were significantly lower during squats under unstable conditions (the BOSU ball) in comparison to stable conditions (Table 2).

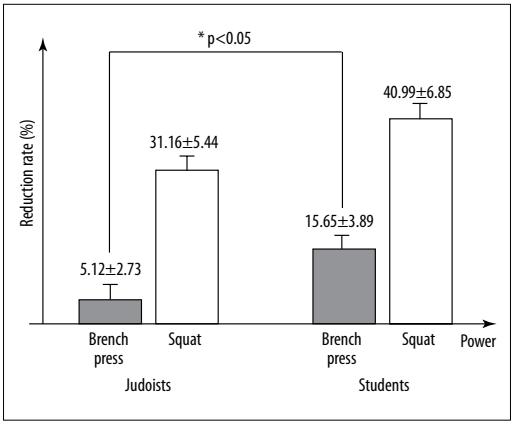

Figure 1. Mean (SD) reduction rates of peak power under unstable conditions in comparison to stable conditions.

Discussion

Physiologically, core strength and stability training are believed to lead to a greater maximal power and more efficient use of the muscles of the shoulders, arms and legs [12]. This, in theory, results in lower risk of injury and has a positive effect on athletic performance in terms of speed, agility, power and aerobic endurance. It is likely that the pre-training performance level of the included participants may have influenced the magnitude of the adaptations. Wahl & Behm [13] reported no significant changes in muscle activity with the use of moderately unstable devices which indicated that the use of these training devices (hemispheric and inflatable discs) did not impart adequate challenges to the neuromuscular system in high resistance trained individuals. Thus, because highly trained individuals may already possess enhanced stability from the use of dynamic free weights, a greater degree of instability may be required for efficiency gains to occur. The possibility of a reduced training load associated with unstable exercises may be compensated by high muscle activation and internal muscle tension, providing similar training stresses [14].

The most important finding in this study was the lack of statistical significant differences in all the examined muscular outputs during bench presses under stable and unstable conditions. On the basis of these results, we can assume that judoist succeeded in stabilizing themselves on the Swiss ball, and compensated for the loss of force at the beginning of the concentric phase of the bench press maneuver, so they could accelerate the upward movement. What is more, it is obvious that they found a way to use the elastic energy of the compressed Swiss ball to increase velocity of movement (60.26 cm·s^{-1} ±11.11) in comparison to stable conditions (59.18 cm·s^{-1} ±7.21). As a result of those sensorimotor abilities, the reduction rate of peak power was only 5.12%±2.73 (Figure 1), and there were no statistically significant differences between peak powers under unstable conditions in comparison to stable conditions (Table 1). Therefore, the bench press as a resistance exercise performed on the Swiss ball with a reduced training load (70% of 1RM) cannot be recommended as an effective training model for high-level judoists. For the students of the Faculty of Sport and Physical Education, who had no experience with the unstable exercises, the Swiss ball provided sufficient challenges to the neuromuscular system which resulted with a statistically significant difference between peak powers under unstable in comparison to stable conditions (Table 2). The significant reductions in muscular outputs (reduction rate 15.65%±3.89; p<0.001) in this group probably occurred because the

muscles around the shoulder complex needed to prioritize stability over force production, which has already been reported in similar studies [15,16]. Because many sports disciplines require the whole body to be stabilized and a large amount of power to be generated in a coordinated manner, for the students of the Faculty of Sport and Physical Education unstable resistance training may be a functional way to improve power.

Both in training and during competitions, judoists are constantly subjected to unexpected movements imposed by their opponents in order to make them fall on a soft surface (*tatami*). Therefore, the good performances of judoists in unusual situations could be due to the fact that training in martial arts develops sensorimotor adaptabilities which are transferable to posture control under other circumstances [17]. Judo requires generating large amounts of power in the upper body while grappling with opponents and maintaining an upright posture and whole body balance; therefore, core-upper limb neuromuscular coordination may have been high in this particular population of athletes when compared with competitors in other sports [18]. On the other hand, there were statistical significant differences in all the examined muscular outputs during squats under unstable compared to stable conditions in both groups (Figure 1). When the participant tries to apply force on BOSU ball, the peak power achieved under stable conditions is not possible because of the significant functions of muscle stabilization. Barbell squats under unstable conditions result in a significant reduction in peak power since the velocity of movement is diminished, while the co-contractions are probably increased and muscle coordination is altered, as it has previosly been reported [19]. However, in the group of judoists, the reduction rate of the velocity of movement under unstable and stable conditions was lower in a statistically significant manner in comparison to the group of students (18.8%±5.01 *vs.* 32.8%±10.42; $p<0.05$). Having this information allow us to recommend squats with reduced training load (70% of 1RM) on the BOSU ball as an effective training model for high-level judoists. In judo practice, the CNS acts to control the position of the body's centre of gravity relative to the feet and organizes postural patterns in a balance task as a function of available sensory information and biomechanical constraints [18,20,21]. In fact, the improvement of postural control concurrent to judo training appears to be a consequence of the better mastery of the common postural strategies available in the controls' repertoire and especially those based on somatosensory input [17]. This characteristic of judo athletes may be reflected in low reduction rates under unstable conditions. It is difficult to generalize the results of this case study because they are based on participants who trained in the same judo club for years and underwent a similar long-lasting adaptation process. Considering the small number of athletes who were involved in the study, more research is needed to establish the effectiveness of resistance training exercises under unstable conditions in the case of high-level judoists before giving precise training recommendations to athletes and coaches.

Conclusions

The results obtained suggest that judo training leads to the best performances in terms of maintaining a stable position of the upper body under all circumstances as the result of privileging somatosensory afferents as an essential component of balance control. Therefore, the bench press as a resistance exercise performed on a Swiss ball with a reduced training load (70% of 1RM) cannot be recommended as an effective training model for high-level judoists because it is not a sufficient stimuli to improve muscle strength. Nevertheless, squats with reduced training load under unstable conditions provided sufficient challenges to the neuromuscular system and could be incorporated into the training programs for judoists. The data obtained during the course of this case study allow us to recommend the squats with a reduced training load (70% of 1RM) performed on a BOSU ball as a potentially effective training model for high-level judoists. The obtained results and determined statistically significant differences between judoists and university students indicate that the techniques and balance strategies learned by high-level judoists should carefully be analyzed to determine if they could be incorporated into training programs for competitors in other sports and into rehabilitation programs for injured participants.

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