Original Article

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Short-term effects of half-squat jump potentiating protocol on power output and countermovement jump performance

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Abstract

The purpose of this study was to determine short-term effect of complex training with inclusion of postactivation potentiation (PAP) on average power output (P_{max}) and countermovement jump (CMJ) in competitive athletes. Sixteen athletes (age: 21.3±3.3 years, height: 178.9 ± 8.6 cm, weight: 74.8±9.9 kg) were pair-matched and randomly assigned into intervention (INT) (n=8), and control group (CON) (n=8). Over a training period of a 6-weeks with training frequency 2 days per week, the subjects underwent pre-, mid- (after 3 weeks), and post-testing (after 6 weeks) in CMJ and P_{max}. Before the start of each training session EXP performed PAP protocol which consisted of 3 sets and 4 repetitions of half-squat jump exercise with individualized loads on (P_{max}), whereas CON continued their normal complex training without the inclusion of PAP. Both groups significantly improved performance after 6 weeks of training. Novel findings of this study have shown that the INT which has been regularly performing PAP protocol before each training session achieved greater gains in P_{max} (16.5 % vs. 4.9 %, $p<0.01$, from pre- to mid-training) and CMJ (15.4 % vs. 8.3 %, $p<0.05$, from pre- to post-training) compared to the CON. In conclusion, it seems that performing potentiating protocols before complex training sessions can potentially enhance motor performance in competitive athletes.

Keywords: postactivation potentiation, explosive strength, maximal average power output, jump squat

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INTRODUCTION

In scientific literature postactivation potentiation (PAP) is characterized by a subsequent increase in muscular force and twitch production due to the previous sub-maximal or maximal dynamic and/or isometric contractile exercises [1]. There are several mechanisms attributed by researchers that are responsible for increases in neuromuscular performance, for instance: 1) higher actin-myosin sensitivity to Ca^{2+} [2,3], 2) increased alfa-motoneuron excitability [4,5], 3) changes in muscle pennation angle [6,7]. Although, the exact mechanism that is responsible for the increase in performance after PAP is still unclear, there are numerous studies where upper-body as well as lower-body muscular performance was acutely improved after heavy or explosive weight exercises [8,9,10,11,12].

When examining lower-body effects of PAP, several research studies reported significant improvements in sprint times over a distance of 20, 30 and 40 m as well as 10 m after sets of heavy squat and half-squat jump preloading stimuli [9,12,13,14]. Significant improvements in vertical jump performance after heavy squats were also recorded [15,16,17]. However, no significant improvements or mixed results in performance after potentiating protocols were also demonstrated [18,19,20]. Many factors may have led to these mixed results, and should be noted (a) the higher strength level of an individual and multiple sets may elicit greater PAP effects [21,22,23], (b) type of conditioning exercise with similar movement pattern replicating subsequent activity may increase the likehood of the PAP effects [15,21], and (c) determine responders and non-responders [24].

With respect to the half-squat jump exercise as a preloading stimulus, to date, only 3 studies examined PAP effects of this exercise [12,14,25]. For instance, Vanderka et al. [12] examined acute effects of 2 sets and 6 repetitions of half-squat jumps on acceleration (0-20 m) and maximum (20 m with flying start) running speed in track and field athletes and soccer players. Sprint performance was significantly enhanced after 4 minutes of rest over both 0-20 m ($\Delta \sim 1.5\%$; $p \leq 0.05$) and 20 m ($\Delta \sim 1\%$; $p \leq 0.05$) in track and field athletes only. Similarly, Suchomel et al. [25] recorded significantly greater improvements in vertical jump performance (jump height, peak power, $p \leq 0.05$) after half-squat exercise performed in a ballistic manner compared to the nonballistic. In contrast, McBride et al. [14] found no significant improvements in a group of footballers after performing 1 set and 3 repetitions of loaded countermovement jumps in the 10-/30-/ and 40 m dash after 4 minutes of rest. Despite the number of studies where acute potentiating effects of different types and modes of exercises were examined, it seems that if the potentiating protocols are well set (with respect to the aforementioned factors) thus positive PAP effects can be achieved. Although, application of such potentiating protocol before competitions seems complicated, and not only from equipment availability standpoint, but also, the beginning of the competition may be prolonged or altered [26]. However, to the authors' knowledge, no previous research has examined short and/or long-term effects of PAP stimuli on multiple sport-specific performances, especially when potentiation protocols are included before the beginning of the complex training session, while it was previously stated that examination of long-term effects of PAP warrants further investigation [27,28]. Therefore, the purpose of this study was to examine and compare a 6-week training program with or without inclusion of half-squat jumps as a potentiating stimulus to the complex training program on multiple sport-specific tasks with overall training volume (sets x reps) equated. It was hypothesized that inclusion of potentiating stimulus to the complex training would produce greater adaptation effects compared to the group without PAP.

MATERIAL AND METHODS

Participants

A group of athletes (soccer, ice hockey, combat sports) were divided to the intervention and control group. Both groups trained for 6 weeks with training frequency 2 days per week. Only the intervention group performed potentiating protocol (PAP) before each training session. Potentiating protocol in the intervention group consisted of half-squat jump exercise. Control group continued their training program which was the same as in the intervention group, but without inclusion the PAP. Before each PAP protocol and training session, standardized warm-up was included. Evaluation was

carried out before, in the middle (3 weeks) and after 6 weeks of training program, and included the following tests: countermovement jump (CMJ) and maximize average power output (P_{max}).
Twenty - two male and five female university students started this experiment. Competitive athletes from different kinds of sports (soccer, ice hockey, combat sports) agreed to participate in this study. Sixteen men completed this study, whereas others were discarded for several reasons (attendance <90%, personal reasons, loss of motivation). The participants were pair-matched according to their maximize average power output and randomly assigned to the intervention group (INT, n=8) (age 23.2±2.95, height 184.73±7.52 cm, weight 79.21±10.4 kg, body weight/weight of barbell=1.34), and the control group (CON, n=8) (age 22.05±1.62, height 181±3.27 cm, weight 75.4±4.39 kg, body weight/weight of barbell=1.44). This study was approved by the local University Ethics Committee and was conducted according to the Declaration of Helsinki. An informed consent form was read and signed by each of the subject prior to the investigation. The participants was had at least 4 years strength training experience. They were fully informed about the study design, training program and evaluation process. All possible risks which could occur during the training or testing were also explained. Ingestion of alcohol, caffeine or other stimulants that could affect performance was strictly forbidden at least 48 hours before each training or testing session.

Procedures

Warm-up and PAP protocol

The participants began each training session with standardized warm-up lasting 10 minutes. Warm-up consisted of 5 minutes running at slow speed first, followed by a dynamic warm-up including ringing the head, ringing by arms, trunk movements (flexion, extension and lateral bending), hip movements in standing position (flexion, extension, abduction and adduction), forward lunges and lateral lunges. The PAP protocol in the intervention group consisted of 3 sets and 4 repetitions of half-squat jumps with the load that maximize average power output, and with barbell placed on the shoulders [12]. Rest period between sets was 2 minutes and the last set of potentiating protocol was executed 8 minutes before main training program. The control group performed only training program without inclusion the PAP protocol. Each participant was instructed about the PAP protocol and correct exercise technique. The knee joint angle (appx. 90°) during the half-squat jumps was individually adjusted for each participant using a hand-held goniometer.

Training protocol

Both groups performed the same training program focused on explosive power and acceleration and maximal running speed. Training program consisted of the following exercises in this order: horizontal jumps, single-leg vertical jumps, throw medicine ball forward and backward overhead, putting medicine ball overhead, acceleration running speed (10 m), maximal running speed (30 m + 10 m with flying start) (Table 1). Total volume after the training program in both groups was equated (number of sets and repetitions). Participants were verbally instructed about exercise technique with an emphasis on maximal intensity.

Measurement

One week before testing, the participants performed 2 familiarization sessions including a series of loaded half-squat jumps and countermovement jumps with an emphasis on exercise technique and proper execution of the tests which are part of the pre-, mid- and post-testing. Testing was carried out in sports hall and laboratories which are part of a university. The same testing procedure as described below was held throughout this study.

Vertical jump height

Countermovement jump height (CMJ) was measured using the Myotest accelerometer system (Myotest® Performance Measuring system, Sion, Switzerland). The device was attached on a stick, which was positioned and held on the participants´ shoulders. All participants were informed to avoid any involuntary movement in the vertical plane during jumps that could affect jump height. The Myotest device has been shown to be valid and reliable to measure CMJ (ICC=0.95, CV=3.3%) [29].

Table 1. Training protocol in experimental and control group

Practice weeks	**Monday** **Rest:** 1min. between sets and reps. **Intensity:** explosive power **Total volume:** Jumps V,H-180 R, throws-240 R, speed ACC,MAX-930 m	**Wednesday** **Rest:** 1min. between sets and reps. **Intensity:** explosive power **Total volume:** Jumps V,H-180 R, throws-240 R, speed ACC,MAX-930 m
1-2 week	1st.running bounds (2x10 reps.) 2nd. push medicinbal forward overhead (2x10 reps.) 3rd.single-leg stride jump(2x10 reps.) 4th.medicinbal power toss overhead (2x10 reps.) 5th.running start acceleration (10x10m) 6th.putting medicinbal overhead (2x10 reps.) 7th.maximal speed 10m flying start (4x30m)	1st.running bounds (2x10 reps.) 2nd. push medicinbal forward overhead (2x10 reps.) 3rd.single-leg stride jump(2x10 reps.) 4th.medicinbal power toss overhead (2x10 reps.) 5th.running start acceleration (10x10m) 6th.putting medicinbal overhead (2x10 reps.) 7th.maximal speed 10m flying start (4x30m)
2-4 week	1st.running bounds (3x10 reps.) 2nd. push medicinbal forward overhead (3x10 reps.) 3rd.single-leg stride jump(3x10 reps.) 4th.medicinbal power toss overhead (3x10 reps.) 5th.running start acceleration (12x10m) 6th.putting medicinbal overhead (3x10 reps.) 7th.maximal speed 10m flying start (5x30m)	1st.running bounds (3x10 reps.) 2nd. push medicinbal forward overhead (3x10 reps.) 3rd.single-leg stride jump (3x10 reps.) 4th.medicinbal power toss overhead (3x10 reps.) 5th.running start acceleration (12x10m) 6th.putting medicinbal overhead (3x10 reps.) 7th.maximal speed 10m flying start (5x30m)
5-6 week	1st.running bounds (4x10 reps.) 3rd.single-leg stride jump(4x10 reps..) 5th.running start acceleration (15x10m)	1st.running bounds (4x10 reps.) 3rd.single-leg stride jump (4x10 reps.) 5th.running start acceleration (15x10m)

Vertical (V) and horizontal (H) jumps; acceleration (ACC) and maximal (MAX) speed; R- repetition, reps-repetitions

Three trials were performed for the CMJ and participants were instructed to perform CMJ test to a self-selected depth. During the test the participants were instructed to jump "as high as possible". Rest intervals between trials were approx. 30 seconds and the highest jump was recorded for further analysis.

Average power output

Average power output from concentric phase of the jump was measured through a diagnostic series of jump squats with maximal effort in the concentric phase of the movement by using the linear position transducer FiTRO Dyne Premium (FiTRONiC Diagnostic and Training Systems LTD, Bratislava, Slovakia). It has been shown to be a reliable device (ICC=0.97) to measure power [30]. During the jump squat, each participant squatted down to a knee angle of approximately 90°, which was controlled through the use of foam cubes. Two trials were performed with each load that gradually increased in 10 kg steps with 3 min rest between trials. The initial load began with 30 kg and the test was terminated upon reaching a plateau or decrease in average power output (P_{max}). Body mass of each participant was included to calculate Pmax. For more detailed description see [12].

Statistical analysis

Analysis of covariance (ANCOVA) with repeated measures was used to assess main effects for time, group and time × group interaction. When F values were significant, Bonferroni post-hoc tests were used to detect detailed changes. Percentage differences (Δ%) between groups were analyzed by independent t-test. Effect size was calculated by Cohen's *d* and interpreted as <0.2 is a small, 0.2-0.7 is a moderate, and >0.7 is a large effect. Testing of assumptions for each dependent variable was performed using the Shapiro-Wilk test and all data were normally distributed. All descriptive statistics and statistical methods were performed using IBM SPSS 20 and data are presented as uncorrected for covariate. Alpha was set at ≤0.05.

RESULTS

Significant time × group interaction in P_{max} was observed (F=8.878, p=0.04). Significant increases in P_{max} from pre- to mid-training (F=9.066, p<0.01, ES=1.21) as well as from pre- to post-training (F=41.542, p<0.05, ES=0.77) in the EXP were observed. No significant improvements from mid- to post-training were detected (p>0.05). In the CON significant improvement in Pmax was observed only from pre- to mid-training (F=6.568, p<0.05, ES=0.44). No other significant improvements or deteriorations in Pmax in the CON were observed. Comparison between the groups revealed significantly larger percentage increases in favor of the EXP only from pre- to mid-training (p<0.01, ES=1.79).

Significant time × group interaction in CMJ was observed (F=5.536, p=0.03). Significant improvements in CMJ from pre- to mid-training (F=34.323, p<0.01, ES=1.11), and pre- to post-training (F=65.991, p<0.01, ES=1.25) in the EXP were observed. Similarly, significant improvements in CMJ from pre- to mid-training (F=19.901, p<0.01, ES=0.46), and pre- to post-training (F=32.296, p<0.01, ES=0.63) were detected in the CON. However, the EXP was significantly better compared to the CON (p<0.05, ES=1.31). Table 2 shows CMJ and Pmax outputs before, in the middle and after the 6 weeks of the training program in the experimental and control group.

DISCUSSION

This study demonstrates positive short-term effects of complex training with inclusion of PAP on average power output and vertical jump height in competitive athletes. Experimental group performed PAP protocol consisting of 3 sets and 4 repetitions of half-squat jumps with the load that maximize average power output while the control group performed only complex training alone.

Table 2. Muscular power (P_{max}) and vertical jump (CMJ) characteristics in the intervention and control group before, in the middle and after 6 weeks of training.

Group	Pre-training	Mid-training	Post-training
Intervention			
P_{max} (W)	1446.3±180.9	1682.2±209**§	1597.6±212.6*
CMJ (cm)	40.4±4.5	45.5±4.6**	46.6±5.3**#
Control			
P_{max} (W)	1520.3±173.4	1590±138.8*	1589.8±132.8
CMJ (cm)	44±5.7	46.7±5.8**	47.7±5.6**

*p<0.05, **p<0.01 compared to pre-training; #p<0.05, §p<0.01 compared to CON

According to the Smilios et al. [31] study, enhancement of speed-power capabilities such as jumping and throwing with the load that maximize power output is the most effective way to further increase performance in trained individuals. Potentiating protocol with P_{max} load may have even greater applicability in training process when applied before the main part of the complex training. Vanderka et al. [12] examined acute effects of 2 sets and 6 repetitions of half-squat jumps with individualized loads that maximize power output of each participant on acceleration (0-20 m) and maximum (20 m with flying start) running speed in track and field athletes and soccer players. Sprint performance was significantly enhanced after 4 minutes of rest over both 0-20 m (~1.5%; $p \le 0.05$) and 20 m (~1%; $p \le 0.05$) in track and field athletes only. In this study, however, we applied similar potentiating protocol as mentioned above [12], and included it before the main part of the complex training compared to the previous work where on the other hand, only acute responses after PAP were examined. Therefore, it is very complicated to compare results obtained from our study, as to our knowledge, this is the first study dealing with short-term effects of potentiation applied to complex training program.

Significant improvements in CMJ were observed in both training groups which is not surprising, because also complex training program alone included sprinting, jumping and throwing, that both groups underwent with the only exception for the experimental group where PAP protocol was added before main part of the training. For instance, Rodríguez-Rosell et al. [32] in their study examined acceleration running speed over 10 and 20 m, countermovement jump as well as maximum strength in soccer players. The intervention group performed their standardized soccer training with inclusion of squats combined with jumps and sprints 2 times per week over 6 weeks whereas control group performed only field soccer training. In the results authors state that intervention group significantly improved all measured variables ($p = 0.004 – 0.001$). On the other hand, our study was not primarily focused on speed training, but participants in both groups performed complex training including several exercises focused on overall motor performance where only experimental group performed PAP before main training session which may provide increased stimulus to enhance the following performance during the training.

Numerous research studies examined effects of various potentiating protocols to improve countermovement jump height [8,33,34], and all obtained significant improvements in CMJ after performing PAP. Our study is the first one to deal with the impact of PAP included in the short-term complex training program over 6 weeks. The results show significant improvements in both groups, but the experimental group was able to improve CMJ and P_{max} to a greater extent compared to the control group (Table 2). These findings may indicate that potentiating protocol in combination with standardized training could act as increased stimulus at least at the beginning of the main training session. Several research studies, for instance, Kilduff et al. [16] showed that optimal time to achieve positive PAP effect may lie in the range 8 to 12 minutes. Also, Crewther et al. [15] showed that 9 elite rugby players who performed PAP prior to the assessment of explosive force and acceleration running speed improved their performance, and these increases were observed at 4 to 12 minutes after finishing the last set of the potentiating exercise.

The paragraph above also suggests the limitations of this study which lie in the fact that duration of the PAP effect is short-term (few minutes) compared to the total duration of training that all participants completed (app. 40 minutes). Therefore, the achieved positive effects may have disappeared at the beginning of the training session. Another limitation of the study is a lack of control of the training intensity after PAP, and thus, we really cannot say if the training intensity at least at the beginning of the training was increased. For future studies we would recommend to determine also responders and non-responders using pre- and post-training measurements as well as to monitor intensity of subsequent, or subset of exercises used during training.

In conclusion, the particular PAP protocol in the form of half-squat jump exercise and complex training sessions used in this study have demonstrated improvements in average power output and countermovement jump performance in athletes who were assigned in the experiment.

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